US-98081-TM-B (N)

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 951 863 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.10.1999 Bulletin 1999/43

(51) Int. Cl.[6]: A61B 5/021

(21) Application number: 99107592.0

(22) Date of filing: 15.04.1999

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 20.04.1998 JP 12389298
13.05.1998 JP 14666898
13.05.1998 JP 14666998
01.06.1998 JP 16583998

(71) Applicant:
Matsushita Electric Industrial Co., Ltd.
Kadoma-shi, Osaka-fu, 571-8501 (JP)

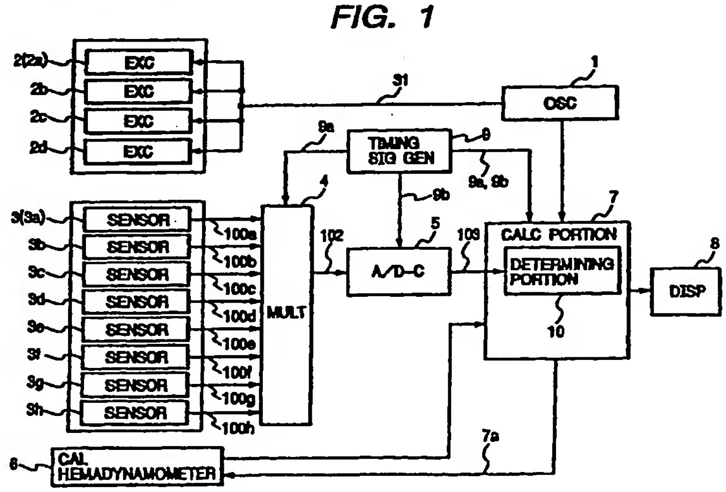
(72) Inventors:
- Hasegawa, Kinya
Sagamihara-shi, Kanagawa-ken 229-1131 (JP)
- Nishimura, Yushi
Yokohama 224-0054 (JP)
- Hagiwara, Hisashi
Yokohama 226-0015 (JP)

(74) Representative:
Manitz, Finsterwald & Partner
Postfach 22 16 11
80506 München (DE)

(54) Method and apparatus for noninvasive continuous blood pressure measurement

(57) Pairs of exciters and sensors are arranged on a substrate in various formations. One pair of an exciter and a sensor is selected in accordance with the detection signal which is derived from an exciter waveform induced in an artery and transmitted therethrough. The arranged on a substrate in various formations. The frequency of the oscillation signal supplied to the exciter is controlled by oscillation signal generation circuits. Bandpass filtering for extracting the exciter waveform, low-pass filtering for extracting a natural blood pressure waveform, phase difference detection processes are provided by a microprocessor. Outputs are selected by a switching circuit and supplied to the microprocessor through one a/d converter. The frequency of the oscillation signal is controlled to an optimum frequency by detecting the detection signal and estimating the attenuation, dispersion, phase shift with respect to different frequencies and by determining one of the frequencies in accordance with the estimation result. The waveform of the oscillation signal is controlled to an optimum waveform, similarly.

FIG. 1



EP 0 951 863 A1

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates to a noninvasive continuous blood pressure measuring apparatus for noninvasively, continuously measuring blood pressure and a method of noninvasively measuring continuous blood pressure.

2. Description of the Prior Art

[0002] A noninvasive continuous blood pressure measuring apparatus for noninvasively, continuously measuring blood pressure is known. An apparatus and a method for measuring an induced perturbation to determine a blood pressure is disclosed in U.S.P. No. 5,590,649. In this prior art apparatus, a monitor for continuously determining a patient's physiological parameter includes a means for obtaining a periodic calibration measurement of the patient's physiological parameter. An exciter, positioned over an artery of the patient induces an exciter waveform into the patient's arterial blood. A noninvasive sensor, positioned over the artery, senses a hemoparameter and provides a noninvasive sensor signal output representative of the hemoparameter. A processor receives the calibration measurement and noninvasive sensor signal output. The processor determines a SC offset based on the calibration measurement and processes the noninvasive sensor signal to continuously determine the patient's physiological parameter.

SUMMARY OF THE INVENTION

[0003] The aim of the present invention is to provide a superior noninvasive continuous blood pressure measuring apparatus and a superior method of noninvasively measuring continuous blood pressure.

[0004] According to this invention, there is provided a first noninvasive continuous blood pressure measuring apparatus including: an oscillator for generating an oscillation signal having a desired frequency and a desired amplitude; a substrate; a plurality of exciters arranged on the substrate in a direction responsive to the oscillation signal for inducing exciter waveforms in an artery and a blood in the artery of a living body; a plurality of sensors respectively arranged on the substrate in the direction a predetermined interval apart from the exciters for receiving induced exciter waveforms transmitted through the artery from the living body and outputting detection signals; a multiplexer for effecting recurrently switching and time-divisionally outputting outputs of the sensors; a determining and selecting portion responsive to the multiplexer for determining one of the outputs in accordance with a predetermined judging condition and for selecting and outputting one of the outputs; a calibration hemadynamometer for detecting absolute values of a maximum blood pressure and a minimum blood pressure of the living body; a calculating portion for receiving the absolute values from the hemadynamometer and successively calculating and outputting an instantaneous blood pressure value from a phase relation between the oscillation signal and one of the outputs from the determining and selecting portion and the absolute values; and a display for displaying a continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion.

[0005] In the first noninvasive continuous blood pressure measuring apparatus, the substrate correspondingly arranges the exciters and the sensors such that each pair of each of the exciters and each of the sensors is arranged in the direction and the exciter and the sensor of each pair are arranged in a second direction perpendicular to the direction, the apparatus further including an attaching unit for attaching the substrate to the living body.

[0006] In the first noninvasive continuous blood pressure measuring apparatus, the substrate may correspondingly arranges the exciter and the sensors such that each pair including two of the sensors and one of the exciter arranged between the two of the sensors with the predetermined distance is arranged in the direction, the apparatus may further include an attaching unit for attaching the substrate to the living body.

[0007] The first noninvasive continuous blood pressure measuring apparatus may further include: a plurality of a/d converters for respectively a/d-converting the detection signals and supplying converted signals to the determining and selecting portion as the outputs of the sensors.

[0008] According to this invention, there is a second noninvasive continuous blood pressure measuring apparatus is provided which includes: an oscillator for generating an oscillation signal having a desired frequency and a desired amplitude; an exciter arranged responsive to the oscillation signal for inducing an exciter waveform in an artery and a blood in the artery of a living body; a sensor arranged a predetermined interval apart from the exciter for receiving the induced exciter waveform transmitted through the artery from the living body and outputting detection signal; a calibration hemadynamometer for detecting absolute values of a maximum blood pressure and a minimum blood pressure of the living body; a calculating portion for receiving absolute values from the calibration hemadynamometer and successively calculating and outputting an instantaneous blood pressure value from a phase relation between the oscillation signal and the detection signal and the absolute values; and a display for displaying a continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion.

[0009] In the second noninvasive continuous blood pressure measuring apparatus, the oscillator may include: a clock signal generation circuit for generating a clock signal; a processor responsive to frequency control data and the clock signal for successively generating frequency signal data indicative of amplitude in time base in accordance with the frequency control data; a d/a converter for converting the frequency signal data; and a filter for low-pass filtering an output of the d/a converter and outputting the oscillation signal of which frequency is controlled in accordance with the frequency data.

[0010] In the second noninvasive continuous blood pressure measuring apparatus, the oscillator may include: a clock signal generation circuit for generating a clock signal; a numerically-controlled oscillator responsive to frequency control data and the clock signal for successively generating frequency signal data indicative of amplitude in time base in accordance with the frequency control data; a d/a converter for converting the frequency signal data; and a filter for low-pass filtering an output of the d/a converter and outputting the oscillation signal of which frequency is controlled in accordance with the frequency data.

[0011] In the second noninvasive continuous blood pressure measuring apparatus, the oscillator may include: a clock signal generation circuit for generating a clock signal; a processor responsive to frequency control data for generating at least one cycle of frequency signal data and storing one cycle of frequency signal data in a look-up table; an address signal generating circuit for generating an address signal in response to the clock signal to operate the look-up table to successively read and output one cycle of frequency data indicative of an amplitude of the oscillation signal; a d/a converter for converting one cycle of frequency data; and a filter for low-pass filtering an output of the a/d converter and outputting the oscillation signal of which frequency is controlled in accordance with the frequency data.

[0012] In the second noninvasive continuous blood pressure measuring apparatus, the oscillator may include: a PLL circuit responsive to frequency control data for successively generating a frequency signal; and a filter for low-pass filtering the frequency signal and outputting the filtered frequency signal as the oscillation signal of which frequency is controlled in accordance with the frequency data.

[0013] According to this invention, there is provided a third noninvasive continuous blood pressure measuring apparatus which includes: an oscillator for generating an oscillation signal having a desired frequency and a desired amplitude; an exciter responsive to the oscillation signal for inducing an exciter waveform in an artery and a blood in the artery of a living body; a sensor arranged a predetermined interval apart from the exciter for receiving the induced exciter waveform transmitted through the artery from the living body and outputting detection signal; an a/d converter for a/d-converting the detection signal; a calibration hemadynamometer for detecting absolute values of a maximum blood pressure and a minimum blood pressure of the living body; a microprocessor including a filter portion and a calculating portion, the filter portion band-pass-filtering the detection signal from the a/d converter, the calculating portion receiving the absolute values from the calibration hemadynamometer and successively calculating and outputting an instantaneous blood pressure value from a phase relation between the oscillation signal and the detection signal from the filter portion and the absolute values; and a display for displaying a continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion.

[0014] According to this invention, there is provided a fourth noninvasive continuous blood pressure measuring apparatus which includes: an oscillator for generating an oscillation signal having a desired frequency and a desired amplitude; an exciter responsive to the oscillation signal for inducing an exciter waveform in an artery and a blood in the artery of a living body; a sensor arranged a predetermined interval apart from the exciter for receiving the induced exciter waveform transmitted through the artery from the living body and outputting detection signal; a calibration hemadynamometer for detecting absolute values of a maximum blood pressure and a minimum blood pressure of the living body; a bandpass filter for band-pass-filtering the detection signal from the sensor; an a/d converter for a/d-converting the detection signal from the bandpass filter; a microprocessor including a calculating portion for receiving the absolute values from the calibration hemadynamometer and successively calculating and outputting an instantaneous blood pressure value from a phase relation between the oscillation signal and the detection signal from the a/d converter and the absolute values; and a display for displaying a continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion.

[0015] According to this invention, there is provided a fifth noninvasive continuous blood pressure measuring apparatus which includes: an oscillator for generating an oscillation signal of which frequency is controlled; an exciter responsive to the oscillation signal for inducing an exciter waveform in an artery and a blood in the artery of a living body; a sensor arranged a predetermined interval apart from the exciter for receiving the induced exciter waveform transmitted through the artery from the living body and outputting detection signal; a calibration hemadynamometer for detecting absolute values of a maximum blood pressure and a minimum blood pressure of the living body; a frequency determining portion responsive to the sensor for controlling the oscillator to successively control the frequency at different frequencies and determining one of the difference frequencies in accordance with the detection signal out-

putted at different frequencies, and then, controlling the oscillator to continuously generate the oscillation signal at one of the different frequencies; a calculating portion responsive to the frequency determining portion for receiving absolute values from the calibration hemadynamometer and successively calculating and outputting an instantaneous blood pressure value from a phase relation between the oscillation signal and the detection signal at one of the different frequencies and the absolute values; and a display for displaying a continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion.

[0016] In the fifth noninvasive continuous blood pressure measuring apparatus, the frequency determining portion may detect attenuations in the detection signal at different frequencies and determine one of the difference frequencies in accordance with a minimum of the attenuations.

[0017] In the fifth noninvasive continuous blood pressure measuring apparatus, the frequency determining portion may detect dispersions in amplitudes of the detection signal at different frequencies and determine one of the different frequencies in accordance with a minimum of the dispersions.

[0018] In the fifth noninvasive continuous blood pressure measuring apparatus, the frequency determining portion may detect phase shifts in the detection signal at different frequencies and determine one of the difference frequencies in accordance with a maximum of the phase shifts.

[0019] In the fifth noninvasive continuous blood pressure measuring apparatus, the frequency determining portion may detect attenuations in the detection signal at different frequencies, detect dispersions in amplitudes of the detection signal at the different frequencies, and detect phase shifts in the detection signal at the different frequencies, obtain estimation values at the different frequencies through an estimating function for estimating the attenuations, the dispersions, and the phase shifts, and determine one of the difference frequencies in accordance with the estimation values at the different frequencies.

[0020] According to this invention, there is provided a sixth noninvasive continuous blood pressure measuring apparatus which includes: an oscillator for generating an oscillation signal of which waveform is controlled; an exciter responsive to the oscillation signal for inducing an exciter waveform in an artery and a blood in the artery of a living body; a sensor arranged a predetermined interval apart from the exciter for receiving the induced exciter waveform transmitted through the artery from the living body and outputting detection signal; a calibration hemadynamometer for detecting absolute values of a maximum blood pressure and a minimum blood pressure of the living body; a waveform determining portion responsive to the sensor for controlling the oscillator to control the oscillation signal successively have different waveforms and determining one of the difference waveforms in accordance with the detection signal outputted at different waveforms and then, controlling the oscillator to continuously generate the oscillation signal at one of the different waveforms; a calculating portion responsive to the frequency determining portion for receiving absolute values from the calibration hemadynamometer and successively calculating and outputting an instantaneous blood pressure value from a phase relation between the oscillation signal and the detection signal at one of the different waveforms and the absolute values; and a displaying for displaying a continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion.

[0021] In the sixth noninvasive continuous blood pressure measuring apparatus, the waveform determining portion may detect attenuations in the detection signal at the different waveforms and determine one of the difference waveforms in accordance with a minimum of the attenuations.

[0022] In the sixth noninvasive continuous blood pressure measuring apparatus, the waveform determining portion may detect dispersions in amplitudes of the detection signal at the different waveforms and determines one of the difference waveforms in accordance with a minimum of the dispersions.

[0023] In the sixth noninvasive continuous blood pressure measuring apparatus, the waveform determining portion may detect phase shifts in the detection signal at the different waveforms and determine one of the difference waveforms in accordance with a maximum of the phase shifts.

[0024] In the sixth noninvasive continuous blood pressure measuring apparatus, the waveform determining portion may detect attenuations in the detection signal at the different waveforms, detect dispersions in amplitudes of the detection signal at the different waveforms, and detect phase shifts in the detection signal at the different waveforms, obtain estimation values at the different waveforms through an estimating function for estimating the attenuations, the dispersions, and the phase shifts, and determine one of the difference waveforms in accordance with the estimation values at the different waveforms.

[0025] According to this invention, there is provided a first method of noninvasively measuring continuous blood pressure including the steps of: generating an oscillation signal of which frequency is controlled; providing an exciter responsive to the oscillation signal inducing an exciter waveform in an artery and a blood in the artery of a living body; providing a sensor arranged a predetermined interval apart from the exciter for receiving the induced exciter waveform transmitted through the artery from the living body and outputting detection signal; detecting absolute values of a maximum blood pressure and a minimum blood pressure of the living body; controlling the oscillation signal to suc-

cessively control the frequency at different frequencies and determining one of the difference frequencies in accordance with the detection signal outputted at different frequencies; continuously generating the oscillation signal at one of the different frequencies; receiving absolute values and successively calculating and outputting an instantaneous blood pressure value from a phase relation between the oscillation signal and the detection signal at one of the different frequencies and the absolute values; and displaying a continuous blood pressure variation from the instantaneous blood pressure successively outputted.

[0026] According to this invention, there is provided a second method of noninvasively measuring continuous blood pressure including the steps of: generating an oscillation signal of which waveform is controlled; providing an exciter responsive to the oscillation signal inducing an exciter waveform in an artery and a blood in the artery of a living body; providing a sensor arranged a predetermined interval apart from the exciter for receiving the induced exciter waveform transmitted through the artery from the living body and outputting detection signal; detecting absolute values of a maximum blood pressure and a minimum blood pressure of the living body; controlling the oscillation signal to successively control the frequency at different waveforms and determining one of the difference waveforms in accordance with the detection signal outputted at different waveforms; continuously generating the oscillation signal at one of the different waveforms; receiving absolute values and successively calculating and outputting an instantaneous blood pressure value from a phase relation between the oscillation signal and the detection signal at one of the different waveforms and the absolute values; and displaying a continuous blood pressure variation from the instantaneous blood pressure successively outputted.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The object and features of the present invention will become more readily apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a first embodiment of this invention;
Fig. 2 is a plan view of a sensor unit of the first embodiment;
Fig. 3 is a cross-sectional side view of the sensor unit of the first embodiment taken on line III-III;
Figs. 4A to 4E are graphical drawings of the first embodiment showing the determining operation;
Fig. 5A is a plan view of a sensor unit of a second embodiment;
Fig. 5B is a cross-sectional side view of the sensor unit of the second embodiment taken on the line VB in Fig. 5A;
Fig. 6 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a third embodiment of this invention;
Fig. 7 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a fourth embodiment of this invention;
Fig. 8 is a block diagram of the fourth embodiment, wherein the operation of the microprocessor is equivalently shown;
Fig. 9 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a fifth embodiment of this invention;
Fig. 10 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a sixth embodiment of this invention;
Fig. 11 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a seventh embodiment of this invention;
Fig. 12 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of an eighth embodiment of this invention;
Figs. 13A and 13B are graphical drawing of the eighth embodiment;
Fig. 14 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a ninth embodiment of this invention;
Fig. 15 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a tenth embodiment of this invention;
Fig. 16 depicts a flow chart of the tenth embodiment showing an operation of the microprocessor;
Fig. 17 depicts a flow chart of the tenth embodiment showing an operation of the frequency determining portion;
Fig. 18 is a graphical drawing of the tenth embodiment;
Fig. 19 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of an eleventh embodiment of this invention;
Fig. 20 depicts a flow chart of the eleventh embodiment showing an operation of the microprocessor; and
Fig. 21 depicts a flow chart of the eleventh embodiment showing an operation of the waveform determining portion.

[0028] The same or corresponding elements or parts are designated with like references throughout the drawings.

DETAILED DESCRIPTION OF THE INVENTION

(FIRST EMBODIMENT)

[0029] Fig. 1 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a first embodiment of this invention. Fig. 2 is a plan view of a

sensor unit of the first embodiment. Fig. 3 is a side cross-sectional view of the sensor unit of the first embodiment taken on line III-III.

[0030] The noninvasive continuous blood pressure measuring apparatus of the first embodiment includes an oscillator 1 for generating an oscillation signal 31 having a predetermined (desired) frequency and a predetermined amplitude, a plurality of exciters 2 (2a to 2d) arranged in a direction X with a distance D1, responsive to the oscillation signal 31, for inducing exciter waveforms in an artery 20 and a blood 23 in the artery 20 of a living body (arm) 21, a plurality of sensors 3 (3a to 3h) arranged in the direction X with a distance D1 and apart from the column of the exciters 2 by a distance D2 respectively for receiving exciter waveforms from the living body 21 and outputting detection signals 100a to 100g, respectively, a timing signal generating circuit 9 for generating timing signals 9a and 9b, a multiplexer 4 for switching and recurrently outputting one of outputs of the sensors 3a to 3h in response to the timing signal 9a, a/d converter 5 for a/d-converting one of the outputs of the sensors 3 from the multiplexer 4, a determining portion 10 responsive to the multiplexer 4 through the a/d converter 5 for determining one of the outputs in accordance with an output of the multiplexer 4 and a predetermined judging condition such as amplitude, a calibration hemadynamometer 6 for detecting absolute values of a maximum blood pressure and a minimum blood pressure of the living body, a calculating portion 7 for operating the calibration hemadynamometer 6 and successively calculating and outputting an instantaneous blood pressure value from a phase relation between the oscillation signal 31 and one of the outputs 100a to 100g indicated by the determination result from the determining portion 10 and the absolute values, and a display 8 for displaying a continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion 7. The calibration hemadynamometer 6 may measure the absolute values of a maximum blood pressure and a minimum blood pressure of the living body periodically without controlling by the calculation portion 7. The distance D2 is constant. On the other hand, the display D1 can be varied with every sensor 3 to surely detect the exciter waveforms.

[0031] The sensor unit 19 includes a substrate 22, the exciters 2a to 2d, and sensors 3a to 3h, and an attaching belt 18 as shown in Fig. 2. The exciters 2 and the sensors 3 includes flexible plates (not shown) and piezoelectric element (not shown) sandwiched between the flexible plates, so called bimorph. The exciter 2 generates vibrations with bending in the plates generated by the piezoelectric elements. Inversely, the sensor 3 generates the detection signal from the piezoelectric element therein in accordance with the vibrations from the living body 21.

[0032] The oscillator 1 generating the oscillation signal 31 having the desired frequency and the predetermined amplitude to induce exciter a favourable waveform in the blood 23 in the artery 20. The exciters 2a to 2d respectively induce exciter waveforms in the artery 20 and the blood 23 in the artery 20 of a living body (arm) 21 in response to the oscillation signal 31. The exciter waveforms (vibrations) induced in the blood 23 transmit through the blood in the artery 20 and reach the sensors 3a to 3d. The sensors 3a to 3h receive exciter waveforms from the living body 21, i.e., the induced exciter waveforms transmitting through the artery 20 and output detection signals 100a to 100g. The timing signal generating circuit 9 generates timing signals 9a and 9b. The multiplexer 4 recurrently selecting and outputting one of detection signals 100a to 100g of the sensors 3a to 3h in response to the timing signal 9a. The aid converter 5 a/d-converts one of the detection signals 100a to 100g of the sensor 3a to 3h. The determining portion 10 determines one of the a/d-converted detection signals in accordance with a/d-converted detection signals and a predetermined judging condition such as amplitude of the detection signals.

[0033] The calibration hemadynamometer 6 detects absolute values of a maximum blood pressure and a minimum blood pressure of the living body 21 periodically or detects the absolute values in response to a command 7a from the calculation portion 7. The calculating portion 7 operates the calibration hemadynamometer 6 and successively calculates and outputs the instantaneous blood pressure value from a phase relation between the oscillation signal 31 and one of the outputs 100a to 100g indicated by the determining result from the determining portion 10 and the absolute values. The display 8 displays the continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion 7.

[0034] The determining operation will be described more specifically.

[0035] Figs. 4A to 4E are graphical drawings of the first embodiment showing the determining operation. For convenience of explanation, it is assumed that one of the detection signals is determined between two detection signals 100c and 100d which are near the artery 20.

[0036] The sensors 100c and 100d outputs the detection signals as shown in Figs. 4A and 4B, wherein an amplitude of the detection signal 100c is higher than that of the detection signal 100d because the exciter 2c and the sensor 3c are just above the artery 20 as shown in Fig. 2.

[0037] The multiplexer 4 multiplexes the detection signals 100c and 100d in response to the timing signal 9a as shown in Fig. 4C.

[0038] The a/d converter 4 a/d-converts the outputs of the multiplexer 4 as shown in Fig. 4D. The determining portion 10 compares the amplitude AMc of the a/d converted detection signal from the sensor 3c with the amplitude AMd of the a/d-converted detection signal 3d with reference to the timing signal 9a and determines

nal as the oscillation signal of which frequency controlled in accordance with the frequency data.

[0049] Fig. 8 is a block diagram of the fourth embodiment, wherein the operation of the microprocessor 210 is equivalently shown.

[0050] The clock signal generation circuit 212 generates the clock signal 215 and a conversion timing signal for the a/d converter 213. The microprocessor 210 starts an operation for calculating frequency signal data 210a indicative of amplitude in response to every clock signal 215 from the clock signal generation circuit 212 using the memory 211 as a work memory by the known double integration method. The a/d converter 213 converts the frequency signal data to generate the oscillation signal. The filter 214 filters the oscillation signal from the a/d converter 213 to remove unnecessary frequency components to supply the oscillation signal 214a with low spurious.

[0051] The calculation portion 7 may be provided by the same microprocessor 210.

[0052] Fig. 8 shows a circuit which is equivalent to the operation of the microprocessor 210.

[0053] The circuit for effecting the double integration method includes first integrator 250, an inverter for inverting an output of the integrator 250, and a second integrator 252 for integrating an output of the inverter 251 and outputting sine data 254 and feed back data which is supplied to the first integrator 250.

[0054] The first integrator 250 includes an adder 253, a multiplier 257, a delay 256. The adder 253 sums the feedback data from a multiplier 260 in the second integrator 252, an output of the delay 256 and a trigger signal 261 which is generated once at start of the operation of the oscillator 1a. The summing result is supplied to the delay 256 and to the multiplier 257 and outputted as a cosine data 255. The multiplier 257 multiplies the cosine data 255 with frequency data "a". The delay 256 supplied with the clock signal 215 delays the summing result of the adder 253 by one clock period of the clock signal 215.

[0055] The inverter 251 having a gain of -1 and inverts the multiplying result.

[0056] The second integrator 252 includes an adder 258, a multiplier 260, and a delay 259. The adder 258 sums an output of the delay 259 and an output of the inverter 251 The summing result of the adder 258 is supplied to the delay 259 and outputted as a sine data 254. The delay 259 supplied with the clock signal 215 delays the summing result of the adder 258 by one clock period of the clock signal 215. The output of the delay 259 is supplied to the multiplier 260 which multiplies the output of the delay 259 with the frequency data "a" and supplies the feedback data to the adder 253 as mentioned. The delay 256 and 259 are supplied with the clock signal 215 to delay the cos data 255 and the sin data 254 by one clock signal interval.

[0057] This circuit generates the oscillation signal 214a of which frequency f is given by:

$$f = (a \times T) / (2 \times \pi)$$

where T is a frequency of the clock signal 215 generated by the clock signal generation circuit 212.

[0058] As mentioned, the circuit generates the oscillation signal 214a of which frequency f is controlled by the frequency control data "a". Moreover, as the oscillation signal, the sine data 254 and the cosine data 255 are generated and are also supplied to the calculation portion 7 at the same time.

(FIFTH EMBODIMENT)

[0059] Fig. 9 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a fifth embodiment of this invention. The noninvasive continuous blood pressure measuring apparatus of the fifth embodiment is substantially the same as that of the fourth embodiment. The difference is in the structure of the oscillator 1b. The oscillator 1b includes a clock signal generation circuit 222 for generating a clock signal; a microprocessor 220 for receiving frequency control data; a numerically -controlled oscillator 221 for successively generating frequency control data indicative of amplitude in time base in accordance with the frequency control data; a d/a converter 223 for converting the frequency signal data, and outputting a frequency signal; and a filter 224 for low-pass-filtering the frequency signal and outputting the filtered frequency signal as the oscillation signal of which frequency controlled in accordance with the frequency data "a".

[0060] The microprocessor 220 receives the frequency control data. The numerically-controlled oscillator 221 successively generates the frequency control data in accordance with the frequency control data. The d/a converter 223 converts the frequency signal data and outputs a frequency signal. The filter 224 low-pass-filters the frequency signal and outputting the filtered frequency signal as the oscillation signal of which frequency controlled in accordance with the frequency data "a".

(SIXTH EMBODIMENT)

[0061] Fig. 10 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a sixth embodiment of this invention. The noninvasive continuous blood pressure measuring apparatus of the sixth embodiment is substantially the same as that of the fourth embodiment. The difference is in the structure of the oscillator 1c. The oscillator 1c includes a clock signal generation circuit 232 for generating a clock signal; a look-up table 231; a microprocessor 230 for receiving frequency control data and generating a set of frequency signal data indicative of amplitude for one cycle of the oscillation signal in accordance with the frequency control data and storing the frequency signal data in a look-up table 231; an address signal genera-

tion circuit 233 for successively generating an address signal in response to the clock signal to operate the look-up table 231 to successively output instantaneous frequency signal data; a d/a converter 234 for a/d-converting the frequency signal data and outputting a frequency signal; and a filter 235 for low-pass-filtering the frequency signal and outputting the filtered frequency signal as the oscillation signal of which frequency controlled in accordance with the frequency data "a".

[0062] The microprocessor 220 receives the frequency control data and generates the set of frequency signal data indicative of amplitude for one cycle of the oscillation signal in accordance with the frequency control data and stores the frequency signal data in the look-up table 231 before the start of measuring the blood pressure. The address signal generation circuit 233 successively generates the address signal in response to the clock signal to operate the look-up table 231 to successively output the instantaneous frequency signal data. The d/a converter 234 d/d-converts the frequency signal data and outputs the frequency signal. The filter 235 low-pass-filters the frequency signal and outputs the filtered frequency signal as the oscillation signal of which frequency controlled in accordance with the frequency data "a".

(SEVENTH EMBODIMENT)

[0063] Fig. 11 is a block diagram of a noninvasive continuous blood-pressure measuring apparatus of a seventh embodiment of this invention. The noninvasive continuous blood pressure measuring apparatus of the seventh embodiment is substantially the same as that of the fourth embodiment. The difference is in the structure of the oscillator. The oscillator 1d of the seventh embodiment includes a microprocessor (MPU) 241 for receiving frequency control data, a PLL circuit 247, and a filter 246. The PLL circuit 247 includes a frequency reference signal generating circuit 240 for generating a frequency reference signal, a phase comparator 242 for detecting a phase difference between the frequency reference signal generating circuit 240 and a frequency-divided signal, an integrator 243 for integrating an output of the phase comparator 242, a voltage-controlled oscillator 245 for generating an oscillation signal of which frequency controlled in accordance with the output of the integrator, i.e., the integrated phase difference, and a frequency divider 244 for frequency-dividing the oscillation signal from the voltage controlled-oscillator 245 by the frequency control data from the microprocessor 241. The filter 246 removes unnecessary components in the oscillation signal from the voltage controlled oscillator 245 and supplies the filtered oscillation signal to the exciter 2 and the calculation portion 7. The frequency of the oscillation signal and the vibration frequency of the exciter 2 are controlled in accordance with the frequency control data.

(EIGHTH EMBODIMENT)

[0064] Fig. 12 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of an eighth embodiment of this invention. The noninvasive continuous blood pressure measuring apparatus of the eighth embodiment is substantially the same as that of the fourth embodiment. The difference is that a microprocessor 301 is further provided for filtering processes and a phase detection process.

[0065] The noninvasive continuous blood pressure measuring apparatus of the eighth embodiment includes the oscillator 1a for generating the oscillation signal 214a of which frequency controlled to a predetermined (desired) frequency and the corresponding oscillation signal data 210a, a bandpass filter 314 for bandpass-filtering the oscillation signal data 210a and outputting frequency reference signal data 314a, the exciter 2 for inducing exciter waveforms in an artery 20 and a blood 23 in the artery of a living body (arm) 21, the sensor 3 apart from the exciter 2 by a distance D2 for receiving exciter waveforms and a natural blood pressure waveform from the living body and outputting detection signal, a pre-amplifier 302 for amplifying the detection signal including a plurality of patient's physiological parameters, an a/d converter 5 for a/d-converting an output of of the pre-amplifier 302 to output detection data, the microprocessor 301 for effecting a bandpass filtering process for detecting the exciter waveform and a low pass filtering process for detecting a natural blood pressure wave form from the detection data and a phase detection process to output phase difference data, a calibration hemadynamometer 6 for detecting absolute values of a maximum blood pressure and a minimum blood pressure of the living body, a calculating portion 7 for successively calculating and outputting an instantaneous blood pressure value from a phase relation between the frequency reference signal data and the detected exciter waveform and the detected natural blood pressure waveform and the absolute values from the calibration hemadynamometer 6, and a display 8 for displaying a continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion 7.

[0066] The bandpass filtering process portion 304 in the microprocessor 301 detects the exciter waveform from the detection data and the low pass filtering process portion 305 detects the natural blood pressure waveform from the detection data. The phase detection process portion 305 detects a phase difference between the frequency reference signal data 314a and the detected exciter waveform from the bandpass processing portion 304 and outputs the phase difference data including a real number component of the phase shift and an imaginarily number component of the phase shift.

[0067] The calculating portion 7 successively calculates and outputs an instantaneous blood pressure

tion circuit 233 for successively generating an address signal in response to the clock signal to operate the look-up table 231 to successively output instantaneous frequency signal data; a d/a converter 234 for a/d-converting the frequency signal data and outputting a frequency signal; and a filter 235 for low-pass-filtering the frequency signal and outputting the filtered frequency signal as the oscillation signal of which frequency controlled in accordance with the frequency data "a".

[0062] The microprocessor 220 receives the frequency control data and generates the set of frequency signal data indicative of amplitude for one cycle of the oscillation signal in accordance with the frequency control data and stores the frequency signal data in the look-up table 231 before the start of measuring the blood pressure. The address signal generation circuit 233 successively generates the address signal in response to the clock signal to operate the look-up table 231 to successively output the instantaneous frequency signal data. The d/a converter 234 d/d-converts the frequency signal data and outputs the frequency signal. The filter 235 low-pass-filters the frequency signal and outputs the filtered frequency signal as the oscillation signal of which frequency controlled in accordance with the frequency data "a".

(SEVENTH EMBODIMENT)

[0063] Fig. 11 is a block diagram of a noninvasive continuous blood-pressure measuring apparatus of a seventh embodiment of this invention. The noninvasive continuous blood pressure measuring apparatus of the seventh embodiment is substantially the same as that of the fourth embodiment. The difference is in the structure of the oscillator. The oscillator 1d of the seventh embodiment includes a microprocessor (MPU) 241 for receiving frequency control data, a PLL circuit 247, and a filter 246. The PLL circuit 247 includes a frequency reference signal generating circuit 240 for generating a frequency reference signal, a phase comparator 242 for detecting a phase difference between the frequency reference signal generating circuit 240 and a frequency-divided signal, an integrator 243 for integrating an output of the phase comparator 242, a voltage-controlled oscillator 245 for generating an oscillation signal of which frequency controlled in accordance with the output of the integrator, i.e., the integrated phase difference, and a frequency divider 244 for frequency-dividing the oscillation signal from the voltage controlled-oscillator 245 by the frequency control data from the microprocessor 241. The filter 246 removes unnecessary components in the oscillation signal from the voltage controlled oscillator 245 and supplies the filtered oscillation signal to the exciter 2 and the calculation portion 7. The frequency of the oscillation signal and the vibration frequency of the exciter 2 are controlled in accordance with the frequency control data.

(EIGHTH EMBODIMENT)

[0064] Fig. 12 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of an eighth embodiment of this invention. The noninvasive continuous blood pressure measuring apparatus of the eighth embodiment is substantially the same as that of the fourth embodiment. The difference is that a microprocessor 301 is further provided for filtering processes and a phase detection process.

[0065] The noninvasive continuous blood pressure measuring apparatus of the eighth embodiment includes the oscillator 1a for generating the oscillation signal 214a of which frequency controlled to a predetermined (desired) frequency and the corresponding oscillation signal data 210a, a bandpass filter 314 for bandpass-filtering the oscillation signal data 210a and outputting frequency reference signal data 314a, the exciter 2 for inducing exciter waveforms in an artery 20 and a blood 23 in the artery of a living body (arm) 21, the sensor 3 apart from the exciter 2 by a distance D2 for receiving exciter waveforms and a natural blood pressure waveform from the living body and outputting detection signal, a pre-amplifier 302 for amplifying the detection signal including a plurality of patient's physiological parameters, an a/d converter 5 for a/d-converting an output of of the pre-amplifier 302 to output detection data, the microprocessor 301 for effecting a bandpass filtering process for detecting the exciter waveform and a low pass filtering process for detecting a natural blood pressure wave form from the detection data and a phase detection process to output phase difference data, a calibration hemadynamometer 6 for detecting absolute values of a maximum blood pressure and a minimum blood pressure of the living body, a calculating portion 7 for successively calculating and outputting an instantaneous blood pressure value from a phase relation between the frequency reference signal data and the detected exciter waveform and the detected natural blood pressure waveform and the absolute values from the calibration hemadynamometer 6, and a display 8 for displaying a continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion 7.

[0066] The bandpass filtering process portion 304 in the microprocessor 301 detects the exciter waveform from the detection data and the low pass filtering process portion 305 detects the natural blood pressure waveform from the detection data. The phase detection process portion 305 detects a phase difference between the frequency reference signal data 314a and the detected exciter waveform from the bandpass processing portion 304 and outputs the phase difference data including a real number component of the phase shift and an imaginarily number component of the phase shift.

[0067] The calculating portion 7 successively calculates and outputs an instantaneous blood pressure

value from the phase difference data, the detected natural blood pressure waveform, and the absolute values from the calibration hemadynamometer 6. The display 8 displays a continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion 7.

[0068] Figs. 13A and 13B are graphical drawing of the eighth embodiment. The sensor receives the vibrations from the living body including the exciter waveform and the natural blood pressure waveform superimposed with each other. The bandpass filtering processing portion 304 extracts the exciter waveform 152 and the low pass filter processing portion 305 extracts the natural blood pressure waveform 151.

[0069] The band pass filter 314 may be omitted if the oscillation signal data 210a includes unnecessary components. The microprocessor 301 may also effect the processing in the calculation portion 7.

(NINTH EMBODIMENT)

[0070] Fig. 14 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a ninth embodiment of this invention. The noninvasive continuous blood pressure measuring apparatus of the ninth embodiment is substantially the same as that of the ninth embodiment. The difference is that the bandpass filtering process is effected by a bandpass filter 404 instead the bandpass filtering processing portion 304, the low pass filtering processing is effected by a low pass filter 405 instead the low pass filtering processing portion 305, a selector 407 is further provided to supplying either of an output of the bandpass filter 404 and an output of the low pass filter 405 to the a/d converter 5.

[0071] The sensor 3 receives the induced exciter waveform and natural blood pressure waveform from the living body and outputting detection signal. The preamplifier 302 amplifies the detection signal including a plurality of patient's physiological parameters. The bandpass filter 404 extracts the exciter waveform. The low pass filter 405 extracts the natural blood pressure waveform. The selector switchably outputs either of the exciter waveform from the bandpass filter 404 or the natural blood waveform from the low pass filter 405 in response to a switching control signal from the microprocessor 301. The a/d converter 5 a/d-converts the exciter waveform and the natural blood pressure waveform. The phase detection process portion 306 detects the phase difference between the frequency reference signal data 314a and an output of the a/d converter 5 while the selector selects the exciter waveform and outputs the phase difference data. The calculating portion 7 successively calculates and outputs an instantaneous blood pressure value from the phase difference data from the phase detection processing portion 306, the natural blood pressure wave form from the a/d converter 5 while the selector 407 selects the natural blood pressure wave form, and the absolute values from the calibration hemadynamometer 6. The display 8 displays a continuous blood pressure variation from the instantaneous blood pressure successively outputted by the calculation portion 7.

(TENTH EMBODIMENT)

[0072] Fig. 15 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of a tenth embodiment of this invention. The noninvasive continuous blood pressure measuring apparatus of the tenth embodiment is substantially the same as that of the fourth embodiment. The difference is that a reference sensor 501 is further provided with the exciter 2, an amplifier 504 for amplifying the reference sensor detection signal from the reference sensor 501, and a a/d converter 505 for a/d-converting the sensor detection signal from the amplifier 504, and a frequency determining portion 509 are further provided. The reference sensor 501 detects the vibrations from the exciter 2. A substrate 502 supports the exciter 2 and the reference sensor 501.

[0073] Fig. 16 depicts a flow chart of the tenth embodiment showing an operation of the microprocessor 508.

[0074] Before detecting the continuous blood pressure, the frequency determining portion 509 successively generates and supplies frequency control data indicative of a frequency fi (f1 to fn) to the oscillator 1a for T seconds and successively detects the detection signal from the sensor 3 and the reference sensor detection signal 503 for the interval of T seconds to determine the optimum frequency and supplies the frequency control data indicative of the optimum frequency in step S551. When the optimum frequency has been determined, the microprocessor 508 successively calculates the instantaneous blood pressure in step S552 at the optimum frequency, so that the display 8 displays the continuous blood pressure variation from the successively supplied blood pressure from the calculation portion 7.

[0075] Fig. 17 depicts a flow chart of the tenth embodiment showing an operation of the frequency determining portion 509, that is, the step S551.

[0076] At first, the frequency determining portion 509 generates the frequency control data indicative of a frequency f1 for the interval of T seconds in step S500. During the interval of T seconds, the oscillator 1a generates the oscillation signal having a frequency f1, i.e., A sin ($2\pi f1t$). The exciter 2 generates vibration of the frequency f1, so that the exciter waveform is induced in the artery 20.

[0077] In the following step S501, the reference sensor 501 detects the vibrations of the exciter 2 and generates the reference sensor detection signal 503 which is supplied to the microprocessor 508 through the amplifier 504 and the a/d converter 505 at the oscillation frequency f1. The sensor 3 detects the exciter waveform transmitted through the artery 20 and generates the

detection signal 3a which is supplied to the microprocessor 508 through the amplifier 506 and the a/d converter 507 at the oscillation frequency f1. Further, the frequency determining portion 509 extracts the frequency component f1 from the detection signal from the sensor 3 and extracts the frequency component f1 of the reference sensor detection signal by a filtering process.

[0078] Moreover, the frequency determining portion 509 effects a quadrature detection to obtain and store a real number component (I component) and an imaginarily number component (Q component) of the phase shift between the frequency reference signal data and the detection signal from the sensor 3. The processing in step S501 is repeated for T seconds.

[0079] Fig. 18 is a graphical drawing of the tenth embodiment.

[0080] When t = T (sec) in step S502, the frequency determining portion 509, in step S503, predicts a circular arc 1901 of the I and Q components ((I1, Q1),(I2, Q2), • • • ,(Im, Qm)) of the phase shift at the frequency f1 in an I-Q plane as shown in Fig. 18 and predicts a center 1902 of the circular arc 1901 and obtains distances, i.e., radiuses, (r1, r2, • • • ,rm) between the respective points (I1, Q1),(I2, Q2), • • • ,(Im, Qm) and the predicted center 1902 of the circular arc 1901 (m is a natural number more than one) and calculates an average radius Rf1AVe and attenuation ratio Pf1 with respect to the amplitude Aex of the reference sensor detection signal from the reference sensor 501 as follows:

$$Pf1 = 1 \cdot (Rf1Ave / Aex)$$

[0081] The frequency determing portion 509, in step S504 calculates a dispersion value Rf1Var of the radiuses r1, r2, • • •, rm. Moreover, optimum frequency estimation value Zfi is obtained:

$$Zf1 = \alpha \cdot (Pf1/PStd) + \beta \cdot (Rf1Var / RStd)$$

[0082] Then, processing returns to step S500 to generates the oscillation signal having a frequency f2.

[0083] The processing from steps S500 to S505 is repeated until i = n (n is a natural number).

[0084] Then, the optimum frequency estimation values of f1 to fn are obtained from the equation:

$$Zfi = \alpha \cdot (Pfi/PStd) + \beta \cdot (RfiVar / RStd)$$

[0085] Then, in step S506, the optimum frequency showing the lowest the optimum frequency estimation value is selected. In the following step S507, the frequency determining portion 509 supplies the frequency control data of the optimum frequency.

[0086] In the equation for obtaining the optimum frequency estimation value, α and β are weighting coefficients which are determined in accordance with degrees of importance of the estimation element of (Pfi / PStd) and (RfiVar / RStd).

[0087] In this embodiment, the reference sensor 501 is used. However, this sensor can be omitted because the amplitude of the vibrations of the exciter 2 is substantially constant over a necessary frequency range. Moreover, it is possible that the amplitudes of the reference sensor detection signal with respect to f1 to fn can be measured and stored in advance to be used in step S501.

(ELEVENTH EMBODIMENT)

[0088] Fig. 19 is a block diagram of a noninvasive continuous blood pressure measuring apparatus of an eleventh embodiment of this invention. The noninvasive continuous blood pressure measuring apparatus of the eleventh embodiment is substantially the same as that of the tenth embodiment. The difference is that the waveform determining portion 1602 is provided instead the frequency determining portion 509.

[0089] Fig. 20 depicts a flow chart of the eleventh embodiment showing an operation of the microprocessor 1603.

[0090] Before detecting the continuous blood pressure, the waveform determining portion 1602 successively generates and supplies waveform control data 1601 indicative of a waveform Wj (j= 1 to n) to the oscillator 1e for T seconds and successively detects the detection signal from the sensor 3 and the reference sensor detection signal 503 for the interval of T seconds to determine the optimum frequency and supplies the frequency control data indicative of the optimum waveform in step S561. When the optimum waveform has been determined, the microprocessor 1603 successively calculates the instantaneous blood pressure in step S562, so that the display 8 displays the continuous blood pressure variation from the successively supplied blood pressure from the calculation portion 7.

[0091] Fig. 21 depicts a flow chart of the eleventh embodiment showing an operation of the waveform determining portion 1602, that is, the step S561.

[0092] At first, the waveform determining portion 1602 generates the waveform control data indicative of a waveform Wj for the interval of T seconds in step S600. During the interval of T seconds, the oscillator 1e generates the oscillation signal having a waveform W1, for example Asin (2 π ft). The exciter 2 generates vibration of the waveform W1, so that the exciter waveform is induced in the artery 20.

[0093] In the following steps S601 to S605, the waveform estimation value is obtained as similar to the steps S501 to S505. The estimation value is given by:

$$Zwj = \alpha \cdot (Pwj/PStd) + \beta \cdot (RwjVar / RStd)$$

[0094] Then, processing returns to step S600 to generates the oscillation signal having a waveform wj.

[0095] The processing from steps S600 to S605 is repeated until j = n (n is a natural number).

[0096] Then, the waveform estimation values of W1 to Wn are obtained from the equation:

[0097] Then, in step S606, the optimum waveform showing the lowest waveform estimation value is selected. In the following step S607, the waveform determining portion 1602 supplies the waveform control data of the optimum waveform.

[0098] In this embodiment, the reference sensor 501 is used. However, this sensor can be omitted because the amplitude of the vibrations of the exciter 2 is substantially constant over waveform W1 to Wn. Moreover, it is possible that the amplitudes of the reference sensor detection signal with respect to waveforms W1 to Wn can be measured and stored in advance to be used in step S601.

Claims

1. A noninvasive continuous blood pressure measuring apparatus comprising:

   oscillating means for generating an oscillation signal having a desired frequency and a desired amplitude;
   a substrate;
   a plurality of exciters arranged on said substrate in a direction responsive to said oscillation signal for inducing exciter waveforms in an artery and a blood in said artery of a living body;
   a plurality of sensors respectively arranged on said substrate in said direction a predetermined interval apart from said exciters for receiving induced exciter waveforms transmitted through said artery from said living body and outputting detection signals;
   switching means for effecting recurrently switching and time-divisionally outputting outputs of said sensors;
   determining and selecting means responsive to said switching means for determining one of said outputs in accordance with an output of said switching means and a predetermined judging condition and for selecting and outputting said one of said outputs;
   calibration hemadynamometer means for detecting absolute values of a maximum blood pressure and a minimum blood pressure of said living body;
   calculating means for receiving said absolute values from said hemadynamometer means and successively calculating and outputting an instantaneous blood pressure value from a phase relation between said oscillation signal and said one of said outputs from said determining and selecting means and said absolute values; and
   displaying means for displaying a continuous blood pressure variation from said instantaneous blood pressure successively outputted by said calculation means.

2. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 1, wherein said substrate correspondingly arranges said exciters and said sensors such that each pair of each of said exciters and each of said sensors is arranged in said direction and said exciter and said sensor of each pair are arranged in a second direction perpendicular to said direction; and

   attaching means for attaching said substrate to said living body.

3. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 1, further comprising:

   a substrate correspondingly arranging said exciter and said sensors such that each pair including two of said sensors and one of said exciters arranged between said two of said sensors with said predetermined distance is arranged in said direction; and
   attaching means for attaching said substrate to said living body.

4. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 1, further comprising:

   a plurality of a/d converters for respectively a/d-converting said detection signals and supplying converted signals to said determining and selecting means as said outputs of said sensors.

5. A noninvasive continuous blood pressure measuring apparatus comprising:

   oscillating means for generating an oscillation signal having a desired frequency and a desired amplitude;
   an exciter arranged responsive to said oscillation signal for inducing an exciter waveform in an artery and a blood in said artery of a living body;
   a sensor arranged a predetermined interval apart from said exciter for receiving said induced exciter waveform transmitted through said artery from said living body and outputting detection signal;
   calibration hemadynamometer means for detecting absolute values of a maximum blood

pressure and a minimum blood pressure of said living body;
calculating means for receiving absolute values from said calibration hemadynamometer means and successively calculating and outputting an instantaneous blood pressure value from a phase relation between said oscillation signal and said detection signal and said absolute values; and
displaying means for displaying a continuous blood pressure variation from said instantaneous blood pressure successively outputted by said calculation means.

6. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 5, wherein said oscillation means comprises:

clock signal generation means for generating a clock signal;
a processor responsive to frequency control data and said clock signal for successively generating frequency signal data indicative of amplitude in time base in accordance with said frequency control data;
a d/a converter for converting said frequency signal data; and
filter means for low-pass filtering an output of said d/a converter and outputting said oscillation signal of which frequency is controlled in accordance with said frequency data.

7. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 5, wherein said oscillation means comprises:

clock signal generation means for generating a clock signal;
a numerically-controlled oscillator responsive to frequency control data and said clock signal for successively generating frequency signal data indicative of amplitude in time base in accordance with said frequency control data:
a d/a converter for converting said frequency signal data; and
filter means for low-pass filtering an output of said d/a converter and outputting said oscillation signal of which frequency is controlled in accordance with said frequency data.

8. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 5, wherein said oscillation means comprises:

clock signal generation means for generating a clock signal;
a processor responsive to frequency control data for generating one cycle of frequency signal data and storing said one cycle of frequency signal data in a look-up table;
address signal generating means for generating an address signal in response to said clock signal to operate said look-up table to successively read and output the one cycle of frequency data indicative of an amplitude of said oscillation signal;
a d/a converter for converting said one cycle of frequency data; and
filter means for low-pass filtering an output of said a/d converter and outputting said oscillation signal of which frequency is controlled in accordance with said frequency data.

9. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 5, wherein said oscillation means comprises:

a PLL circuit responsive to frequency control data for successively generating a frequency signal; and
filter means for low-pass filtering said frequency signal and outputting the filtered frequency signal as said oscillation signal of which frequency is controlled in accordance with said frequency data.

10. A noninvasive continuous blood pressure measuring apparatus comprising:

oscillating means for generating an oscillation signal having a desired frequency and a desired amplitude;
an exciter responsive to said oscillation signal for inducing an exciter waveform in an artery and a blood in said artery of a living body;
a sensor arranged a predetermined interval apart from said exciter for receiving said induced exciter waveform transmitted through said artery from said living body and outputting detection signal;
an a/d converter for a/d-converting said detection signal;
calibration hemadynamometer means for detecting absolute values of a maximum blood pressure and a minimum blood pressure of said living body;
a microprocessor including filter means and calculating means, said filter means bandpass-filtering said detection signal from said a/d converter, said calculating means receiving said absolute values from said calibration hemadynamometer means and successively calculating and outputting an instantaneous blood pressure value from a phase relation between said oscillation signal and said detection signal from said filter means and said

absolute values; and
displaying means for displaying a continuous blood pressure variation from said instantaneous blood pressure successively outputted by said calculation means.

11. A noninvasive continuous blood pressure measuring apparatus comprising:

oscillating means for generating an oscillation signal having a desired frequency and a desired amplitude;
an exciter responsive to said oscillation signal for inducing an exciter waveform in an artery and a blood in said artery of a living body;
a sensor arranged a predetermined interval apart from said exciter for receiving said induced exciter waveform transmitted through said artery from said living body and outputting detection signal;
calibration hemadynamometer means for detecting absolute values of a maximum blood pressure and a minimum blood pressure of said living body;
bandpass filter means for band-pass-filtering said detection signal from said sensor;
an a/d converter for a/d-converting said detection signal from said bandpass filter means;
a microprocessor including calculating means for receiving said absolute values from said calibration hemadynamometer means and successively calculating and outputting an instantaneous blood pressure value from a phase relation between said oscillation signal and said detection signal from said a/d converter and said absolute values; and
displaying means for displaying a continuous blood pressure variation from said instantaneous blood pressure successively outputted by said calculation means.

12. A noninvasive continuous blood pressure measuring apparatus comprising:

oscillating means for generating an oscillation signal of which frequency is controlled;
an exciter responsive to said oscillation signal for inducing an exciter waveform in an artery and a blood in said artery of a living body;
a sensor arranged a predetermined interval apart from said exciter for receiving said induced exciter waveform transmitted through said artery from said living body and outputting detection signal;
calibration hemadynamometer means for detecting absolute values of a maximum blood pressure and a minimum blood pressure of said living body;
frequency determining means responsive to said sensor for controlling said oscillating means to successively control said frequency at different frequencies, determining one of said difference frequencies in accordance with said detection signal outputted at different frequencies, and then, controlling said oscillating means to continuously generating said oscillation signal at said one of said different frequencies;
calculating means responsive to said frequency determining means for receiving absolute values from said calibration hemadynamometer means and successively calculating and outputting an instantaneous blood pressure value from a phase relation between said oscillation signal and said detection signal at said one of said different frequencies and said absolute values; and
displaying means for displaying a continuous blood pressure variation from said instantaneous blood pressure successively outputted by said calculation means.

13. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 12, wherein said frequency determining means detects attenuations in said detection signal at different frequencies and determines said one of said difference frequencies in accordance with a minimum of said attenuations.

14. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 12, wherein said frequency determining means detects dispersions in amplitudes of said detection signal at different frequencies and determines said one of said different frequencies in accordance with a minimum of said dispersions.

15. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 12, wherein said frequency determining means detects phase shifts in said detection signal at different frequencies and determines said one of said difference frequencies in accordance with a maximum of said phase shifts.

16. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 12, wherein said frequency determining means detects attenuations in said detection signal at different frequencies, detects dispersions in amplitudes of said detection signal at said different frequencies, and detects phase shifts in said detection signal at said different frequencies, obtains estimation values at said different frequencies through an estimating function for estimating said attenuations, said dis-

persions, and said phase shifts, and determines said one of said difference frequencies in accordance with the estimation values at said different frequencies.

17. A noninvasive continuous blood pressure measuring apparatus comprising:

oscillating means for generating an oscillation signal of which waveform is controlled;
an exciter responsive to said oscillation signal for inducing an exciter waveform in an artery and a blood in said artery of a living body;
a sensor arranged a predetermined interval apart from said exciter for receiving said induced exciter waveform transmitted through said artery from said living body and outputting detection signal;
calibration hemadynamometer means for detecting absolute values of a maximum blood pressure and a minimum blood pressure of said living body;
waveform determining means responsive to said sensor for controlling said oscillation means to control said oscillation signal successively have different waveforms and determining one of said difference waveforms in accordance with said detection signal outputted at different waveforms and then, controlling said oscillating means to continuously generating said oscillation signal at said one of said different waveforms;
calculating means responsive to said frequency determining means for receiving absolute values from said calibration hemadynamometer means and successively calculating and outputting an instantaneous blood pressure value from a phase relation between said oscillation signal and said detection signal at said one of said different waveforms and said absolute values; and
displaying means for displaying a continuous blood pressure variation from said instantaneous blood pressure successively outputted by said calculation means.

18. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 17, wherein said waveform determining means detects attenuations in said detection signal at said different waveforms and determines said one of said difference waveforms in accordance with a minimum of said attenuations.

19. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 17, wherein said waveform determining means detects dispersions in amplitudes of said detection signal at said different waveforms and determines said one of said difference waveforms in accordance with a minimum of said dispersions.

20. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 17, wherein said waveform determining means detects phase shifts in said detection signal at said different waveforms and determines said one of said difference waveforms in accordance with a maximum of said phase shifts.

21. The noninvasive continuous blood pressure measuring apparatus as claimed in claim 17, wherein said waveform determining means detects attenuations in said detection signal at said different waveforms, detects dispersions in amplitudes of said detection signal at said different waveforms, and detects phase shifts in said detection signal at said different waveforms, obtains estimation values at said different waveforms through an estimating function for estimating said attenuations, said dispersions, and said phase shifts, and determines said one of said difference waveforms in accordance with the estimation values at said different waveforms.

22. A method of noninvasively measuring continuous blood pressure comprising the steps of:

(a) generating an oscillation signal of which frequency is controlled;
(b) providing an exciter responsive to said oscillation signal inducing an exciter waveform in an artery and a blood in said artery of a living body;
(c) providing a sensor arranged a predetermined interval apart from said exciter for receiving said induced exciter waveform transmitted through said artery from said living body and outputting detection signal;
(d) detecting absolute values of a maximum blood pressure and a minimum blood pressure of said living body;
(e) controlling said oscillation signal to successively control said frequency at different frequencies;
(f) determining one of said difference frequencies in accordance with said detection signal outputted at different frequencies;
(g) continuously generating said oscillation signal at said one of said different frequencies;
(h) receiving absolute values and successively calculating and outputting an instantaneous blood pressure value from a phase relation between said oscillation signal and said detection signal at said one of said different frequencies and said absolute values; and

(i) displaying a continuous blood pressure variation from said instantaneous blood pressure successively outputted.

23. The method as claimed in claim 22, further comprising the step of:

detecting attenuations in said detection signal at different frequencies, wherein in said step (f), said one of said difference frequencies is determined in accordance with a minimum of said attenuations.

24. The method as claimed in claim 22, further comprising the step of: detecting dispersions in amplitudes of said detection signal at different frequencies, wherein in said step (f) said one of said difference frequencies is determined in accordance with a minimum of said dispersions.

25. The method as claimed in claim 22, further comprising the step of:

detecting phase shifts in said detection signal at different frequencies, wherein in said step (f) said one of said difference frequencies is determined in accordance with a maximum of said phase shifts.

26. The method as claimed in claim 22, further comprising the steps of:

detecting attenuations in said detection signal at different frequencies;
detecting dispersions in amplitudes of said detection signal at said different frequencies;
detecting phase shifts in said detection signal at said different frequencies;
obtaining estimation values at said different frequencies through an estimating function for estimating said attenuations, said dispersions, and said phase shifts; and
determining said one of said difference frequencies in accordance with the estimation values at said different frequencies.

27. A method of noninvasively measuring continuous blood pressure comprising the steps of:

(a) generating an oscillation signal of which waveform is controlled;
(b) providing an exciter responsive to said oscillation signal inducing an exciter waveform in an artery and a blood in said artery of a living body;
(c) providing a sensor arranged a predetermined interval apart from said exciter for receiving said induced exciter waveform transmitted through said artery from said living body and outputting detection signal;
(d) detecting absolute values of a maximum blood pressure and a minimum blood pressure of said living body;
(e) controlling said oscillation signal to successively control said frequency at different waveforms;
(f) determining one of said difference waveforms in accordance with said detection signal outputted at different waveforms;
(g) continuously generating said oscillation signal at said one of said different waveforms;
(h) receiving absolute values and successively calculating and outputting an instantaneous blood pressure value from a phase relation between said oscillation signal and said detection signal at said one of said different waveforms and said absolute values; and
(i) displaying a continuous blood pressure variation from said instantaneous blood pressure successively outputted.

28. The method as claimed in claim 27, further comprising the step of:

detecting attenuations in said detection signal at said different waveforms, wherein in said step (f), said one of said difference waveforms is determined in accordance with a minimum of said attenuations.

29. The method as claimed in claim 27, further comprising the step of: detecting dispersions in amplitudes of said detection signal at said different waveforms, wherein in said step (f) said one of said difference waveforms is determined in accordance with a minimum of said dispersions.

30. The method as claimed in claim 27, further comprising the step of:

detecting phase shifts in said detection signal at different waveforms, wherein in said step (f) said one of said difference waveforms is determined in accordance with a maximum of said phase shifts.

31. The method as claimed in claim 27, further comprising the steps of:

detecting attenuations in said detection signal at said different waveforms;
detecting dispersions in amplitudes of said detection signal at said different waveforms;
detecting phase shifts in said detection signal at said different waveforms;
obtaining estimation values at said different

waveforms through an estimating function for estimating said attenuations, said dispersions, and said phase shifts; and

determining said one of said difference waveforms in accordance with the estimation values at said different waveforms.

FIG. 1

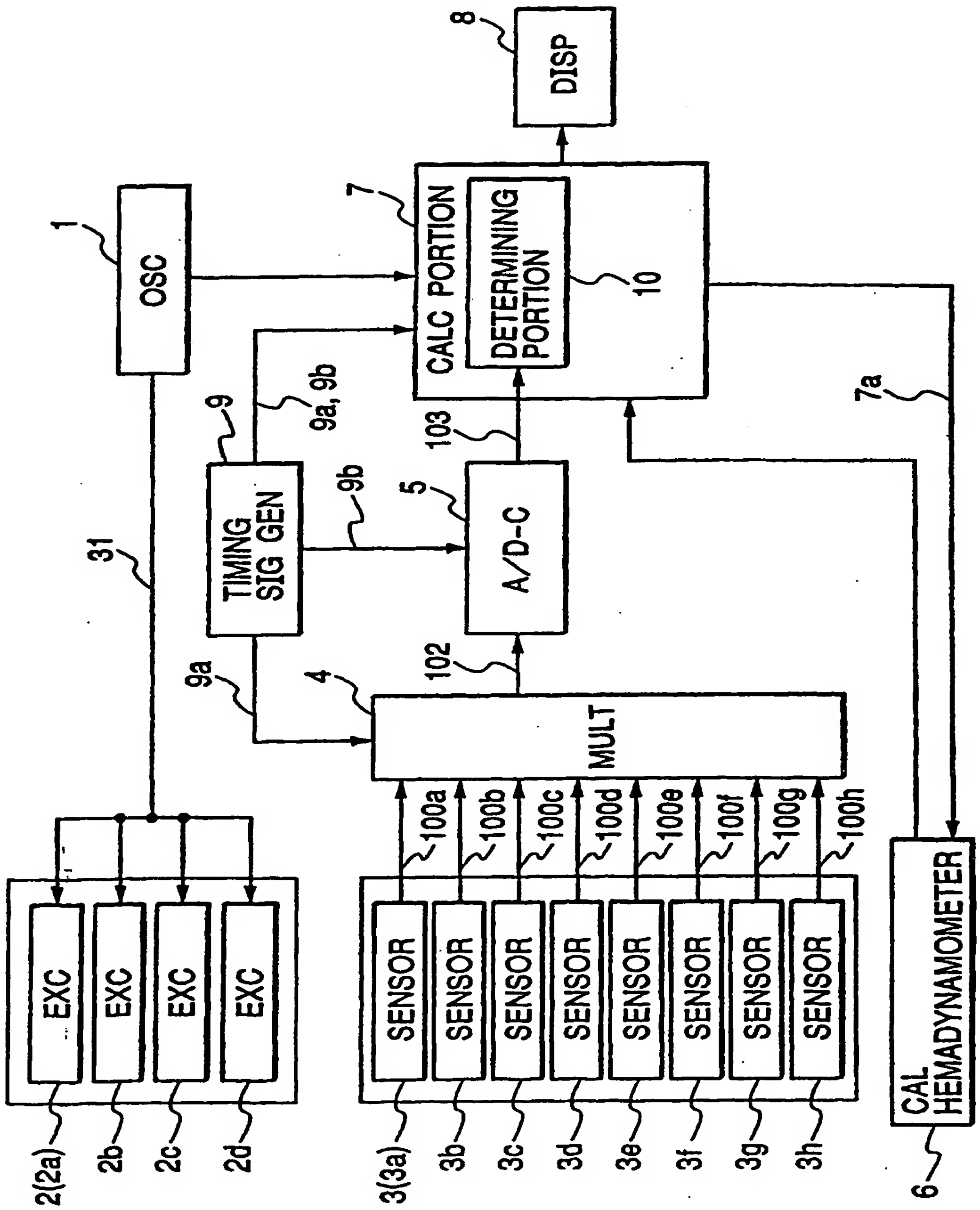

OSC
1
CALC PORTION
7
DETERMINING PORTION
10
DISP
8
TIMING SIG GEN
9
9a, 9b
9b
9a
31
A/D-C
5
103
102
MULT
4
7a
EXC
EXC
EXC
EXC
2(2a)
2b
2c
2d
SENSOR
SENSOR
SENSOR
SENSOR
SENSOR
SENSOR
SENSOR
SENSOR
3(3a)
3b
3c
3d
3e
3f
3g
3h
100a
100b
100c
100d
100e
100f
100g
100h
CAL HEMADYNAMOMETER
6

FIG. 2

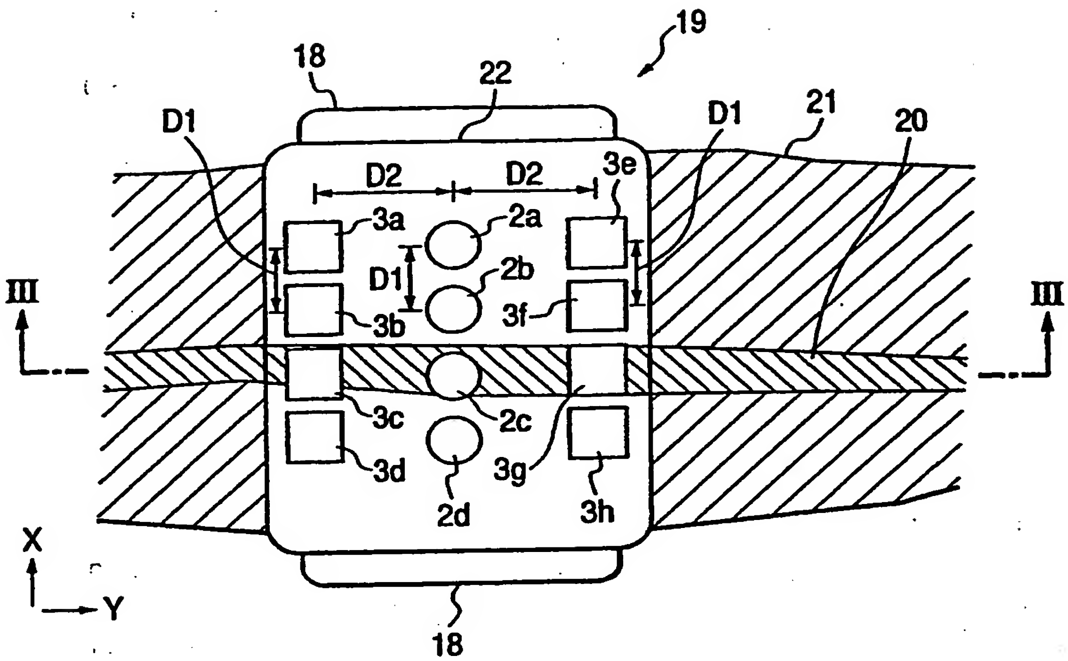

19
18
22
D1
D1
21
20
D2
D2
3e
3a
2a
2b
D1
III
III
3b
3f
3c
2c
3d
3g
2d
3h
X
Y
18

FIG. 3

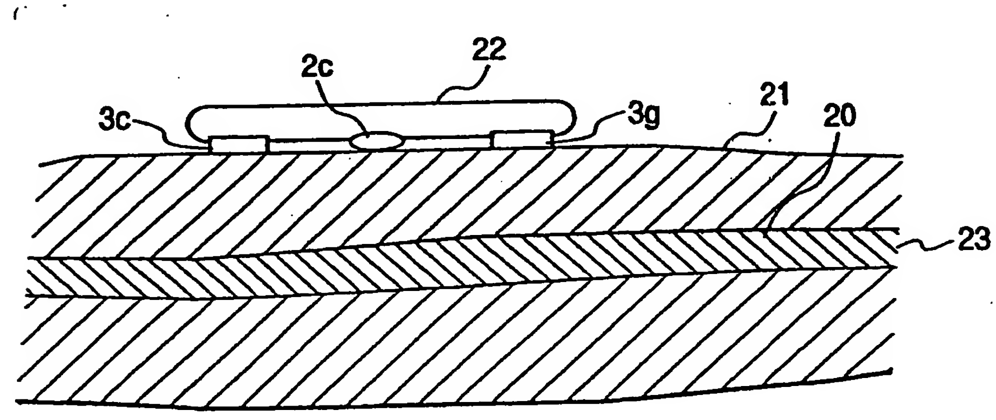

2c
22
21
3c
3g
20
23

FIG. 4A

FIG. 4B

FIG. 4C

FIG. 4D

FIG. 4E

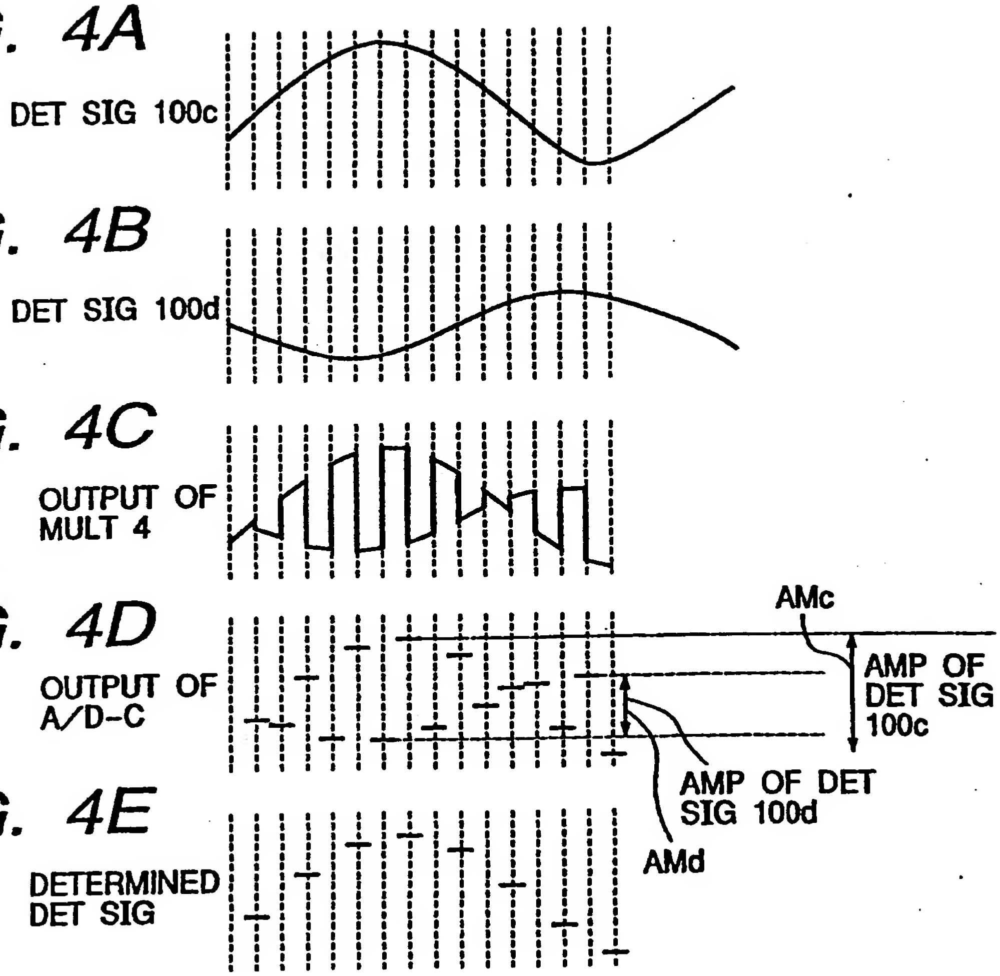


FIG. 5A

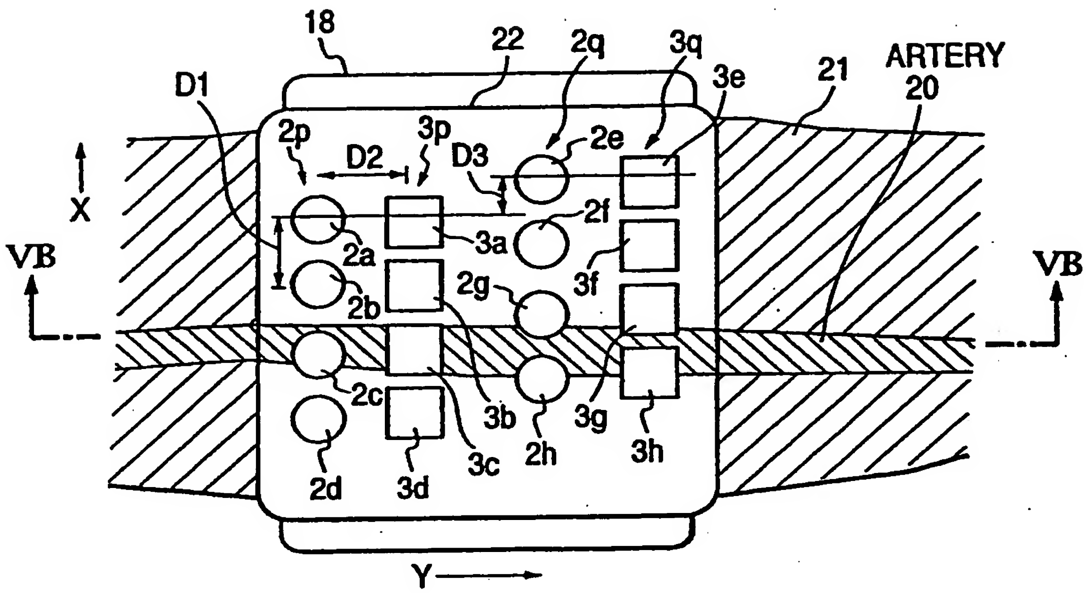

18
22
2q
3q
3e
21
ARTERY
20
D1
2p
3p
D2
D3
2e
X
2a
3a
2f
VB
VB
2b
2g
3f
2c
3b
3g
2h
3h
3c
2d
3d
Y

FIG. 5B

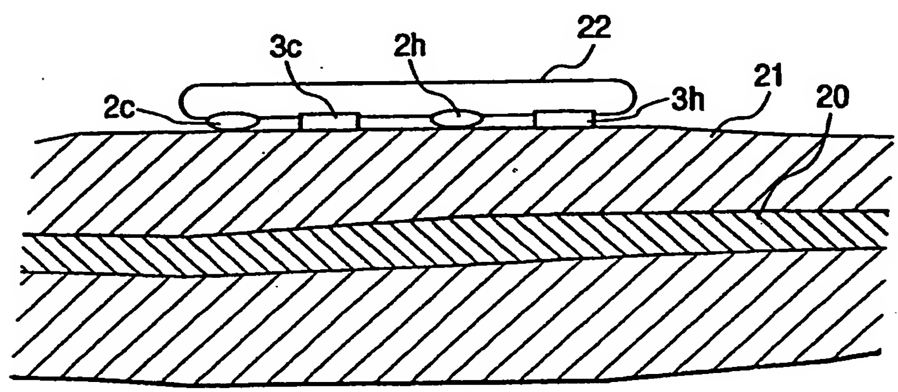

22
3c
2h
21
2c
3h
20
21

FIG. 6

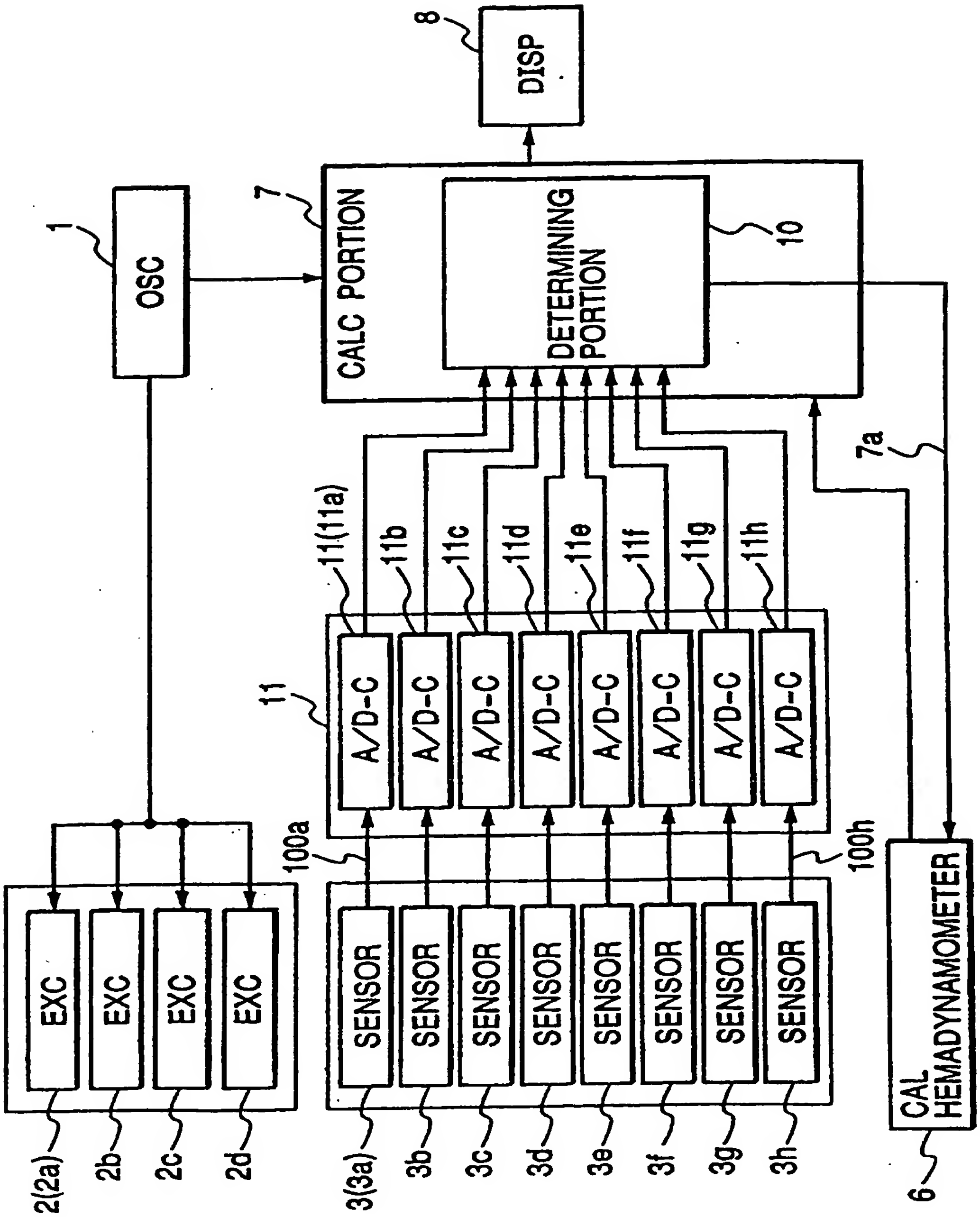

OSC
1
CALC PORTION
7
DETERMINING PORTION
10
DISP
8
EXC
EXC
EXC
EXC
2(2a)
2b
2c
2d
SENSOR
SENSOR
SENSOR
SENSOR
SENSOR
SENSOR
SENSOR
SENSOR
3(3a)
3b
3c
3d
3e
3f
3g
3h
100a
100h
A/D-C
A/D-C
A/D-C
A/D-C
A/D-C
A/D-C
A/D-C
A/D-C
11
11(11a)
11b
11c
11d
11e
11f
11g
11h
7a
CAL HEMADYNAMOMETER
6

FIG. 7

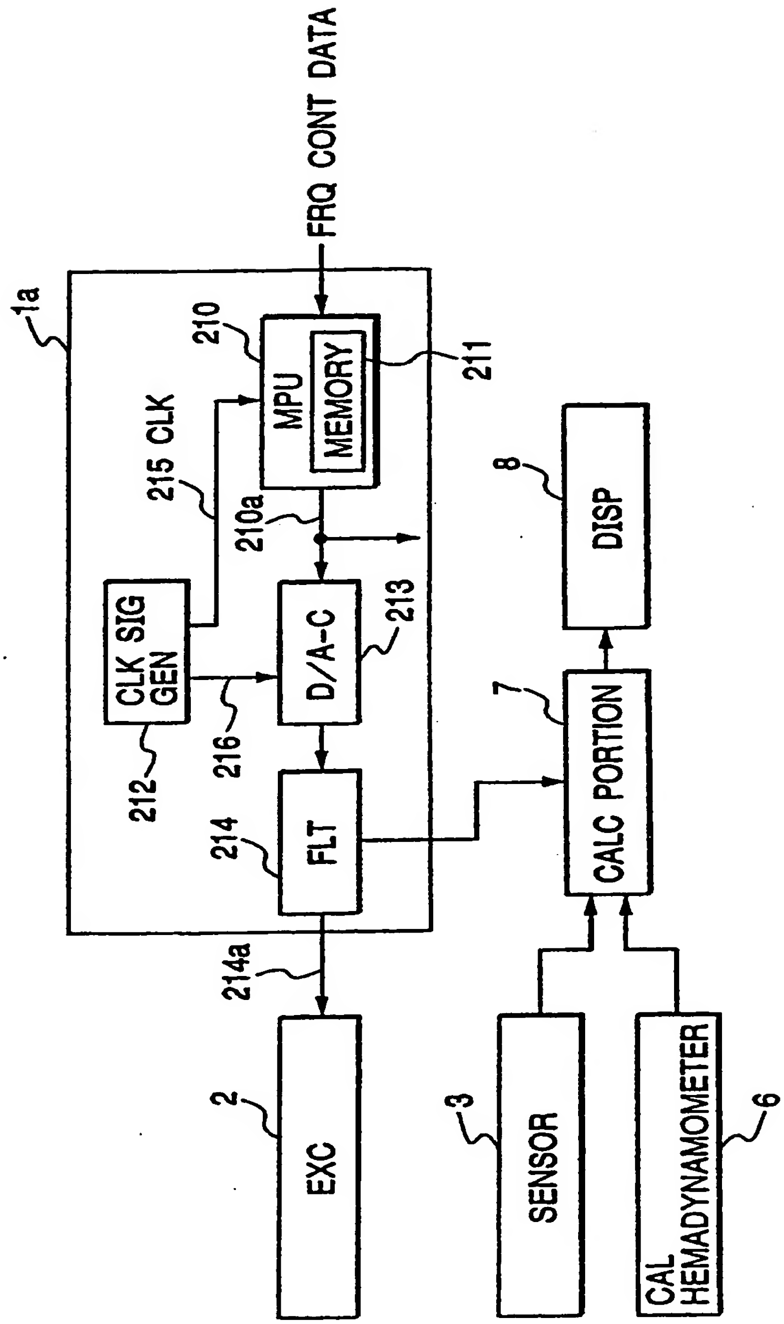

FRQ CONT DATA
1a
210
MPU
MEMORY
211
215 CLK
210a
CLK SIG GEN
D/A-C
213
212
216
FLT
214
214a
8
DISP
7
CALC PORTION
2
EXC
3
SENSOR
CAL HEMADYNAMOMETER
6

FIG. 8

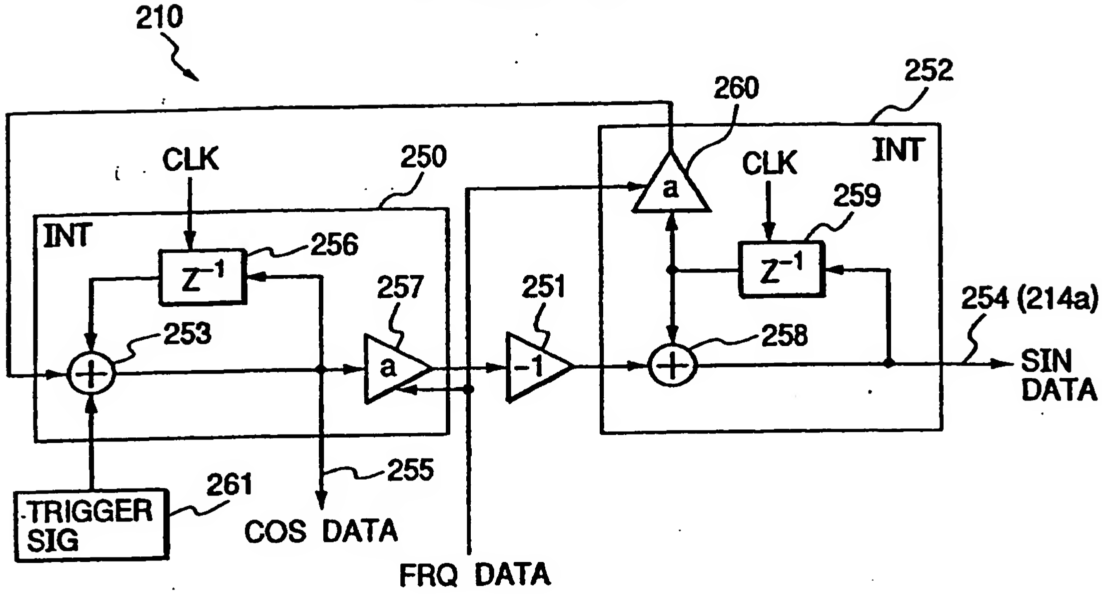

210
CLK
250
INT
256
257
253
a
TRIGGER SIG
261
COS DATA
255
FRQ DATA
251
-1
260
252
a
CLK
INT
259
258
254 (214a)
SIN DATA

FIG. 9

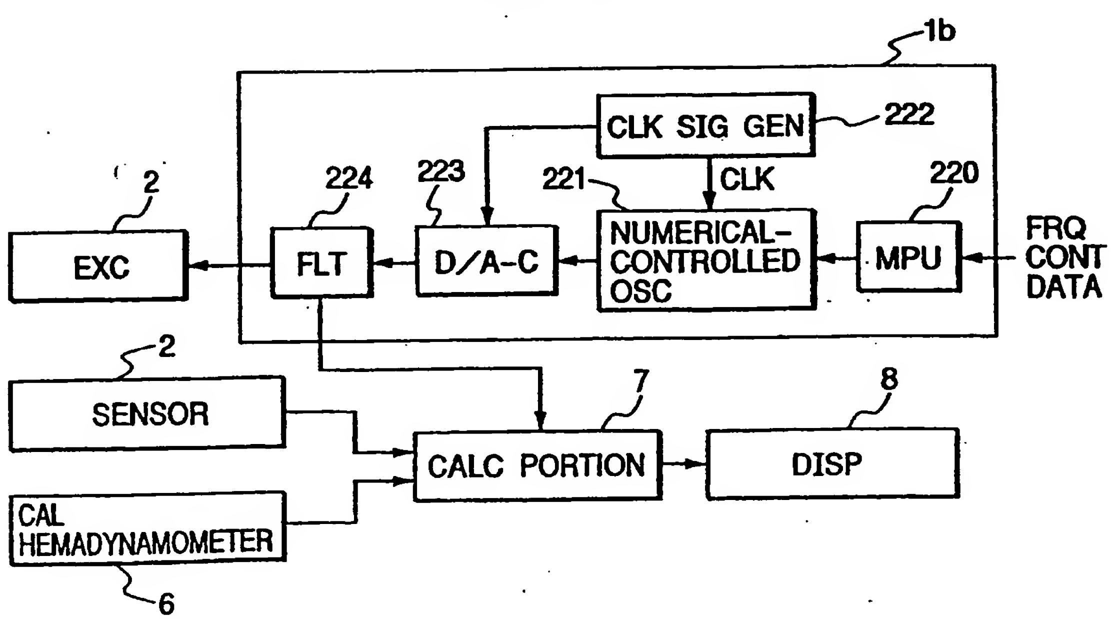

1b
CLK SIG GEN
222
CLK
224
223
221
220
2
EXC
FLT
D/A-C
NUMERICAL-CONTROLLED OSC
MPU
FRQ CONT DATA
2
SENSOR
7
8
CALC PORTION
DISP
CAL HEMADYNAMOMETER
6

FIG. 10

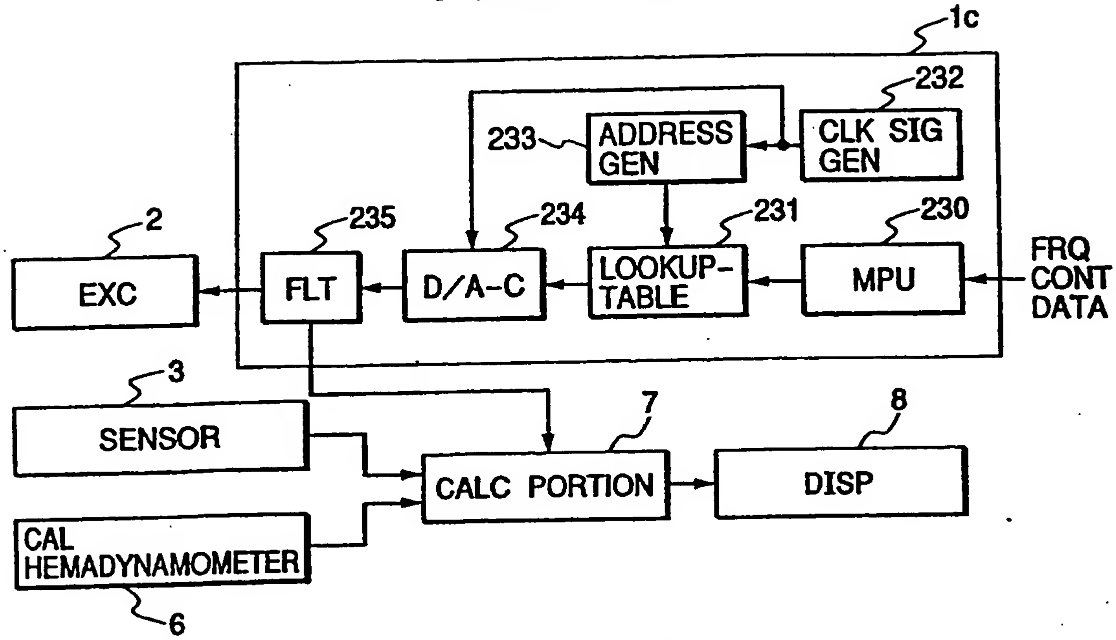

1c
232
233
ADDRESS GEN
CLK SIG GEN
2
235
234
231
230
EXC
FLT
D/A-C
LOOKUP-TABLE
MPU
FRQ CONT DATA
3
7
8
SENSOR
CALC PORTION
DISP
CAL HEMADYNAMOMETER
6

FIG. 11

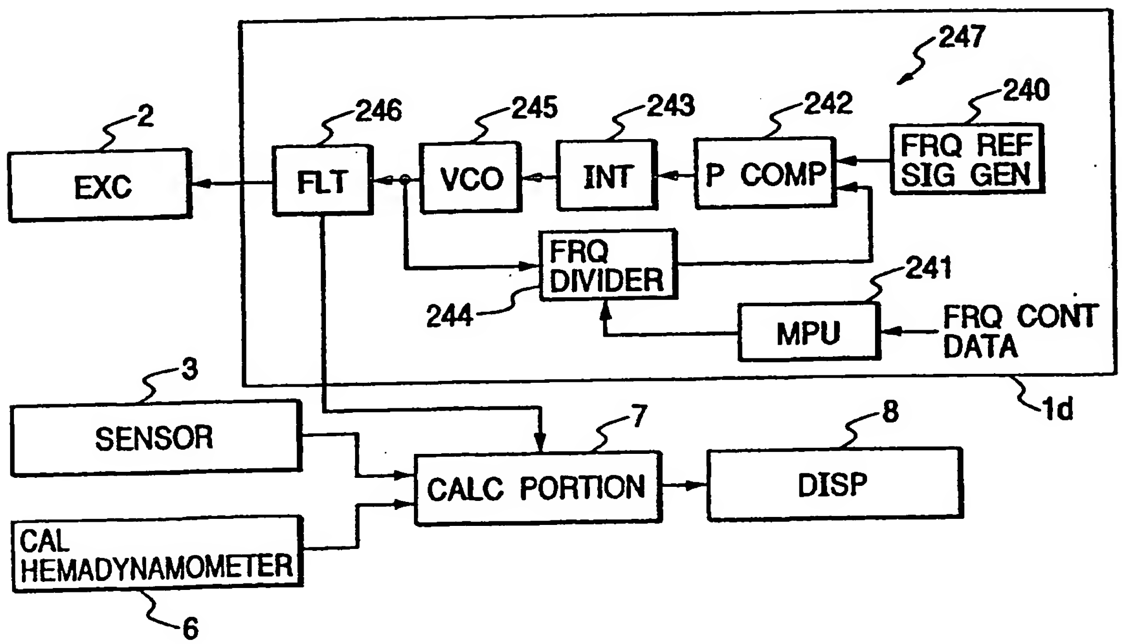

247
240
2
246
245
243
242
EXC
FLT
VCO
INT
P COMP
FRQ REF SIG GEN
FRQ DIVIDER
241
244
MPU
FRQ CONT DATA
3
1d
7
8
SENSOR
CALC PORTION
DISP
CAL HEMADYNAMOMETER
6

FIG. 12

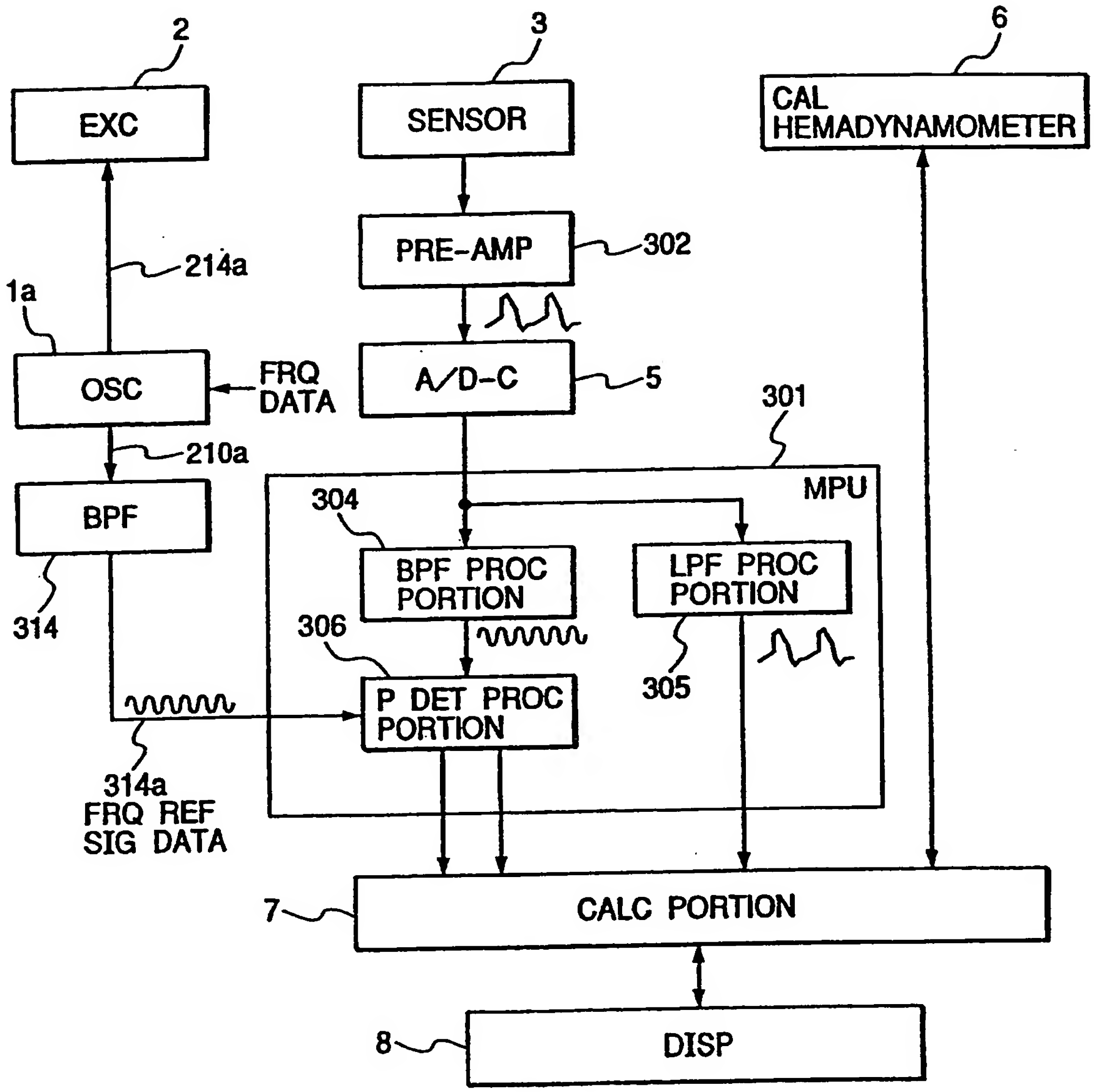

2
EXC
214a
1a
OSC
FRQ DATA
210a
BPF
314
314a
FRQ REF SIG DATA
3
SENSOR
PRE-AMP
302
A/D-C
5
301
MPU
304
BPF PROC PORTION
306
P DET PROC PORTION
LPF PROC PORTION
305
6
CAL HEMADYNAMOMETER
7
CALC PORTION
8
DISP

FIG. 13A

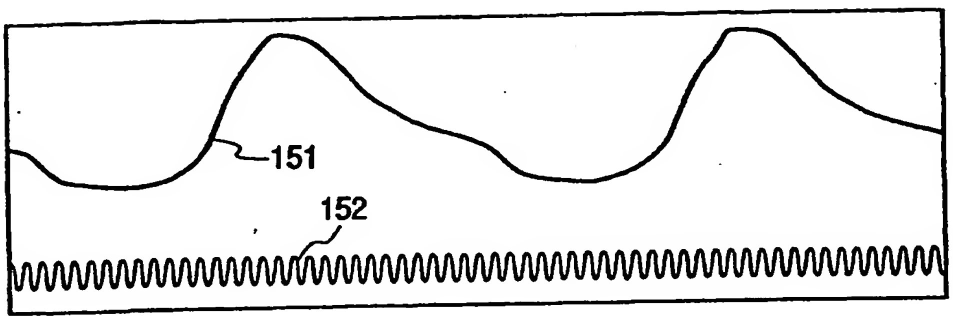


FIG. 13B

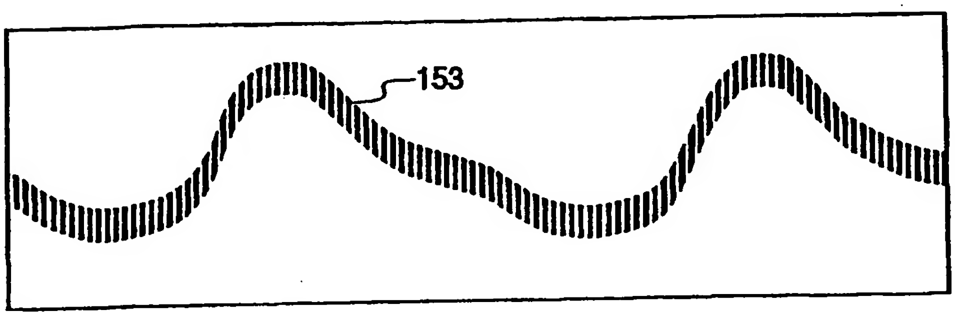


FIG. 14

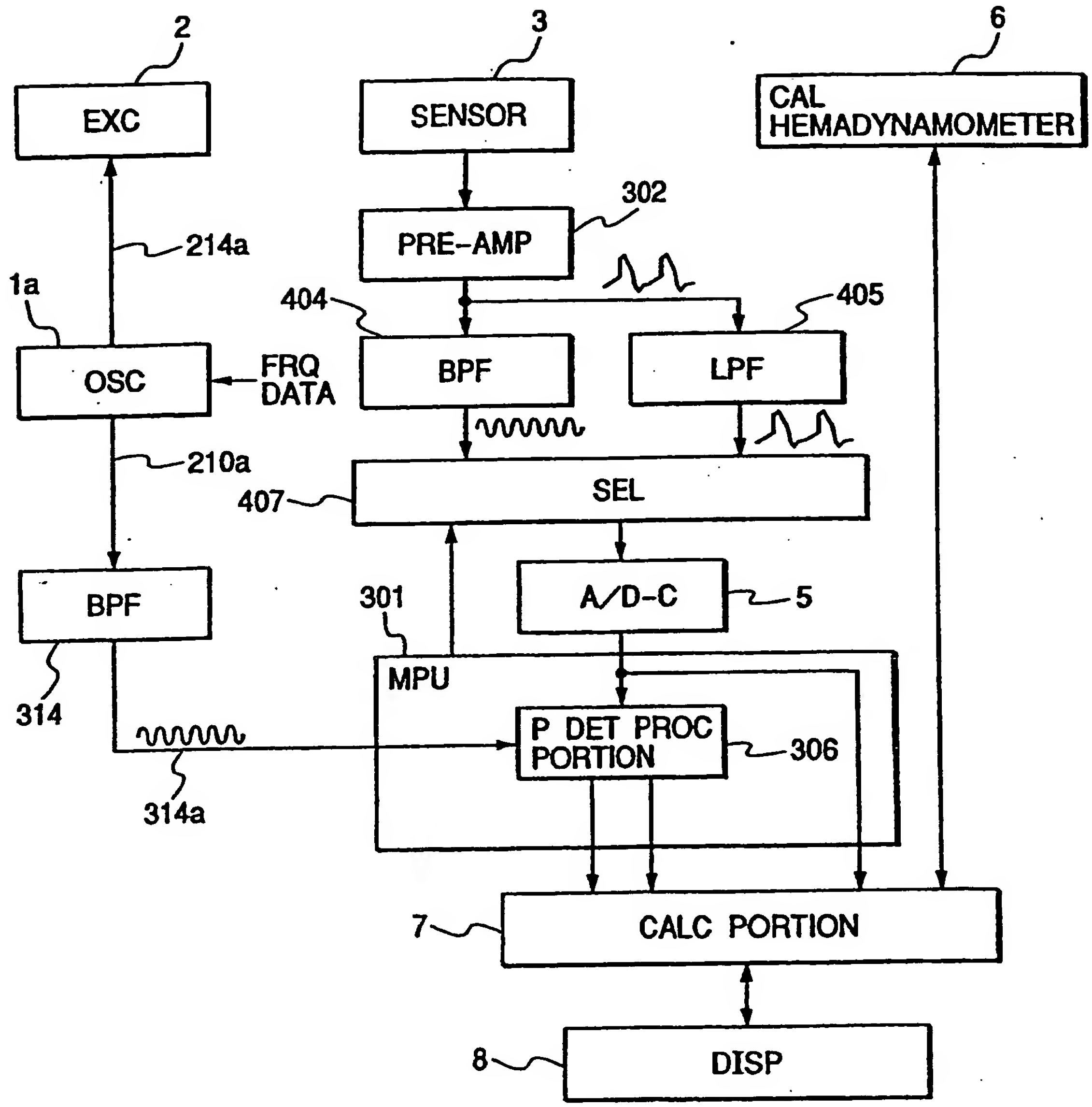

2
EXC
3
SENSOR
6
CAL
HEMADYNAMOMETER
302
PRE-AMP
214a
1a
404
405
OSC
FRQ
DATA
BPF
LPF
210a
407
SEL
BPF
301
A/D-C
5
MPU
314
P DET PROC
PORTION
306
314a
7
CALC PORTION
8
DISP

FIG. 15

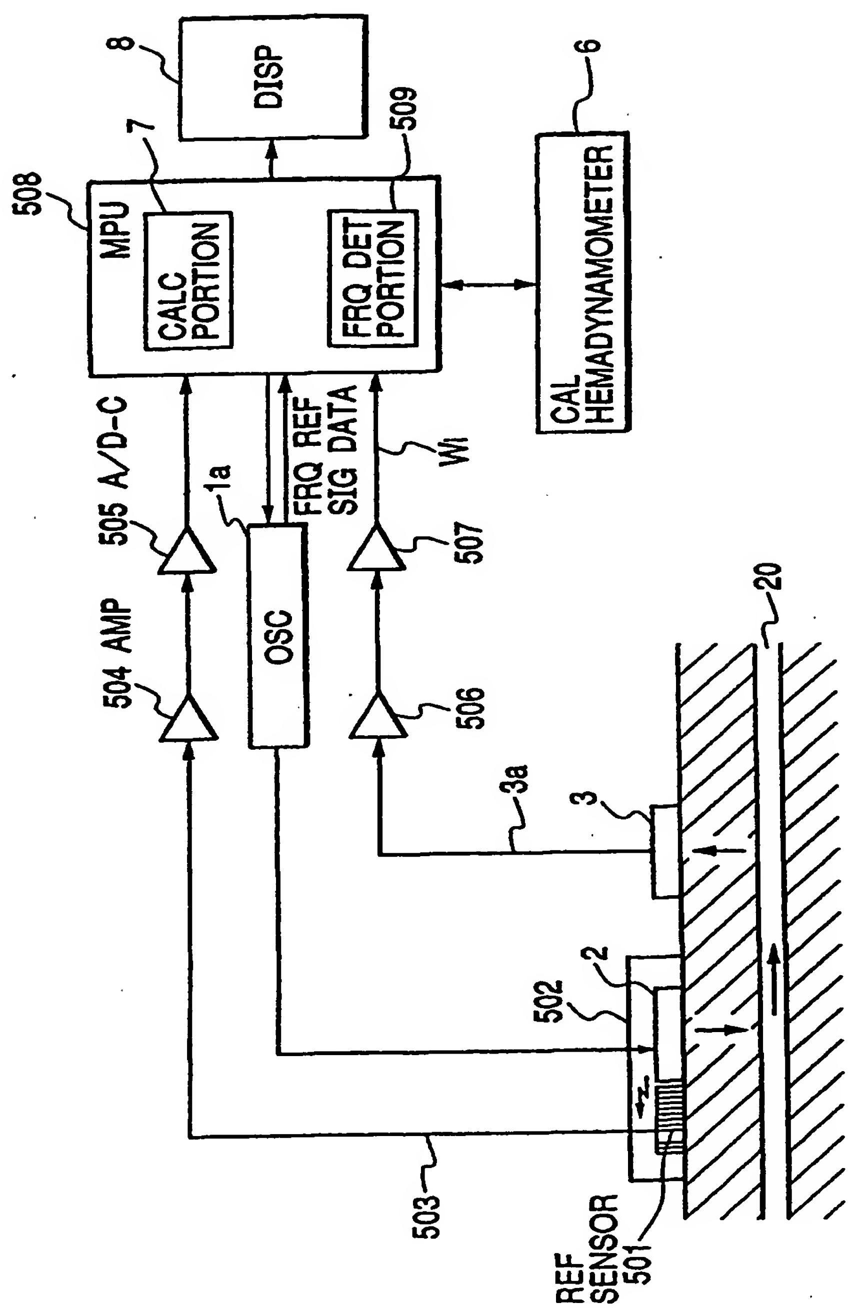

8
DISP
508
MPU
7
CALC PORTION
509
FRQ DET PORTION
6
CAL HEMADYNAMOMETER
504 AMP
505 A/D-C
1a
OSC
FRQ REF SIG DATA
Wi
506
507
3a
3
2
502
503
REF SENSOR 501
20

FIG. 16

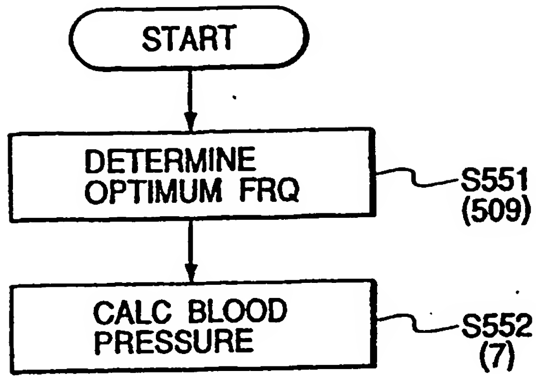

START
DETERMINE OPTIMUM FRQ
S551 (509)
CALC BLOOD PRESSURE
S552 (7)

FIG. 18

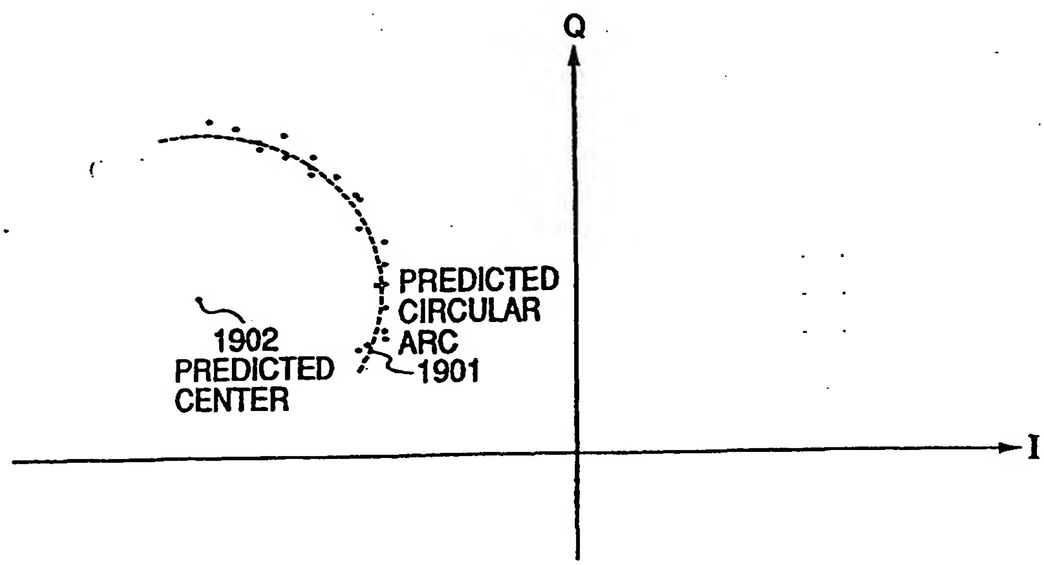

Q
I
PREDICTED CIRCULAR ARC
1901
1902
PREDICTED CENTER

FIG. 17

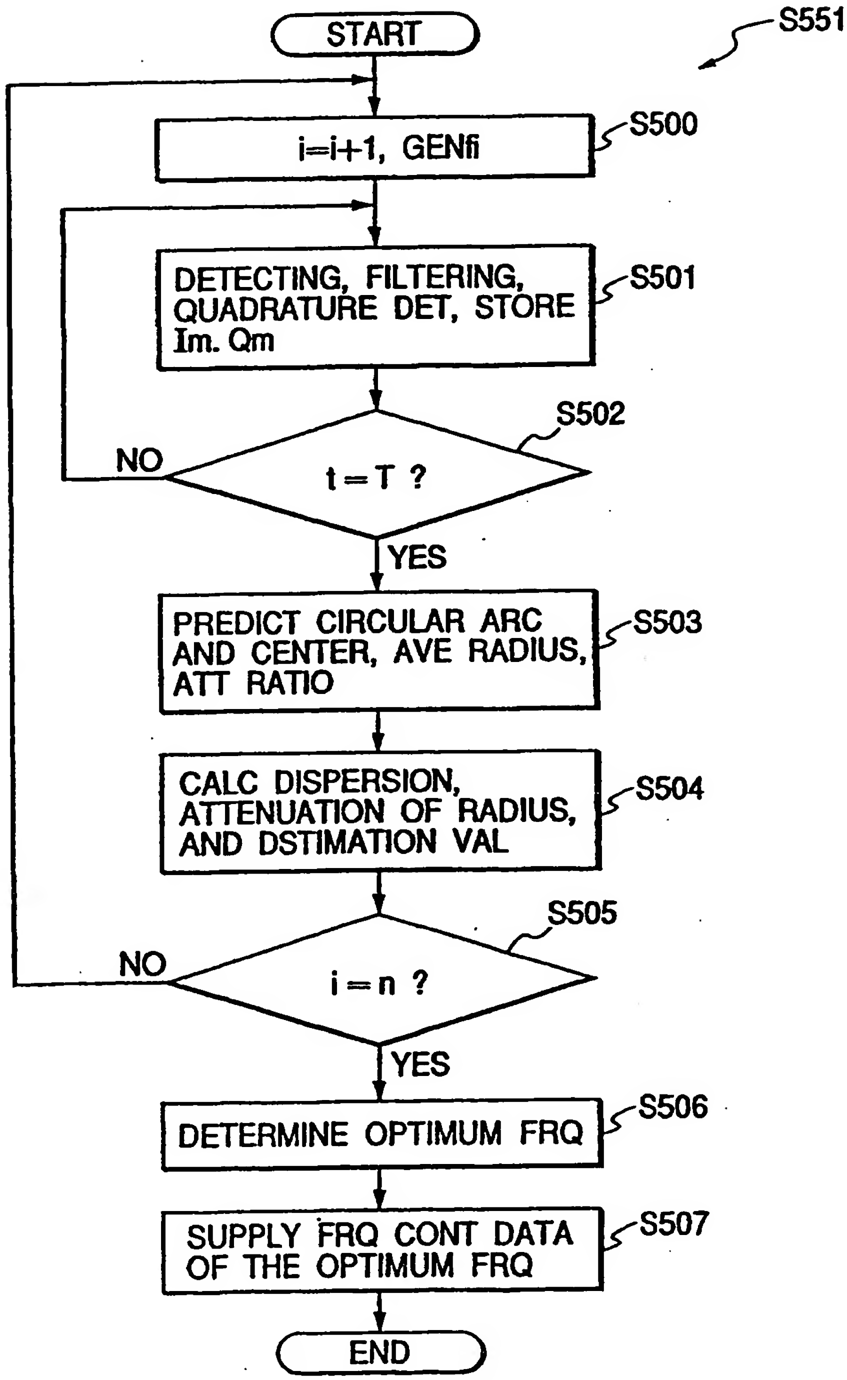

S551
START
i=i+1, GENfi
S500
DETECTING, FILTERING, QUADRATURE DET, STORE Im. Qm
S501
S502
NO
t=T ?
YES
PREDICT CIRCULAR ARC AND CENTER, AVE RADIUS, ATT RATIO
S503
CALC DISPERSION, ATTENUATION OF RADIUS, AND DSTIMATION VAL
S504
S505
NO
i=n ?
YES
DETERMINE OPTIMUM FRQ
S506
SUPPLY FRQ CONT DATA OF THE OPTIMUM FRQ
S507
END

FIG. 19

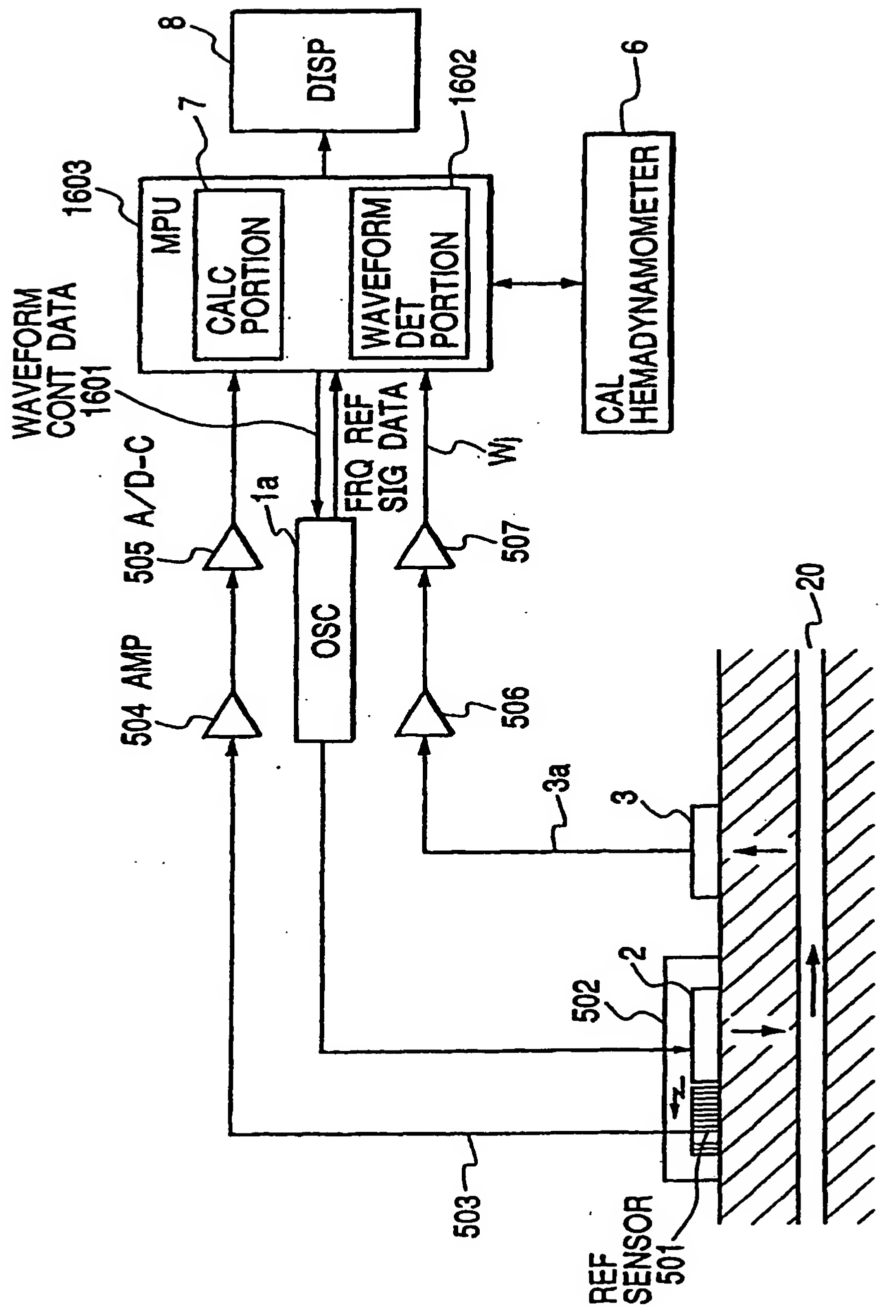

8
DISP
7
1602
6
1603
MPU
CALC PORTION
WAVEFORM DET PORTION
CAL HEMADYNAMOMETER
WAVEFORM CONT DATA
1601
505 A/D-C
504 AMP
1a
OSC
FRQ REF SIG DATA
Wj
507
506
3a
3
2
502
503
REF SENSOR 501
20

FIG. 20

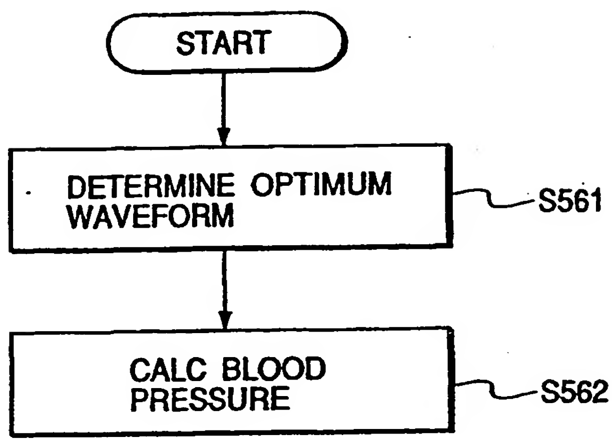
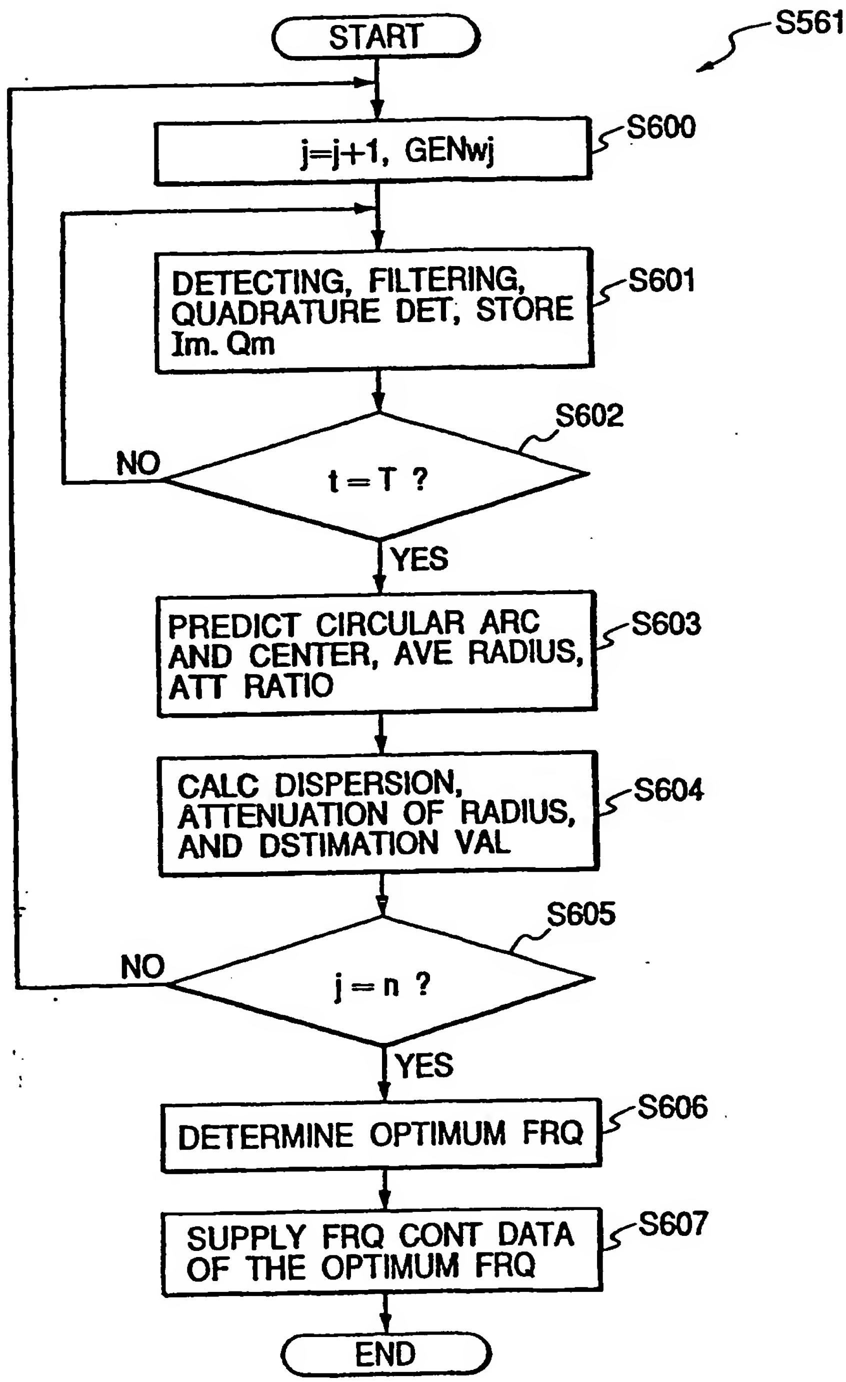

START
DETERMINE OPTIMUM WAVEFORM
S561
CALC BLOOD PRESSURE
S562

FIG. 21


S561
START
j=j+1, GENwj
S600
DETECTING, FILTERING, QUADRATURE DET, STORE Im. Qm
S601
S602
t=T ?
NO
YES
PREDICT CIRCULAR ARC AND CENTER, AVE RADIUS, ATT RATIO
S603
CALC DISPERSION, ATTENUATION OF RADIUS, AND DSTIMATION VAL
S604
S605
j=n ?
NO
YES
DETERMINE OPTIMUM FRQ
S606
SUPPLY FRQ CONT DATA OF THE OPTIMUM FRQ
S607
END

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 10 7592

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,X	US 5 590 649 A (CARO ET AL.) 7 January 1997 (1997-01-07) * column 3, line 33 - column 5, line 14 * * column 9, line 33 - column 10, line 9 * * figures 1-5 *	5	A61B5/021
Y		11,12, 17,22,27	
A		1,8,15, 20	
X	WO 97 49328 A (VITAL INSITE, INC.) 31 December 1997 (1997-12-31) * page 18, line 25 - page 27, line 6 * * figures 8-20 *	10	
Y		11	
A		1,4,5, 15,20, 22,26, 27,30	
Y	SHIMAZU ET AL.: "Vibration technique for indirect measurement of diastolic arterial pressure in human fingers" MEDICAL & BIOLOGICAL ENGINEERING & COMPUTING, vol. 27, no. 2, March 1989 (1989-03), pages 130-136, XP000071965 Stevenage, GB	12,17, 22,27	TECHNICAL FIELDS SEARCHED (Int.Cl.6) A61B
A	* page 132, left-hand column, line 30 - right-hand column, line 33 *	5	
A	WO 97 14355 A (VITAL INSITE, INC.) 24 April 1997 (1997-04-24) * page 3, line 5 - page 5, line 6 * * figures 1-4 *	1,3,5	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	2 August 1999	Chen, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 10 7592

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	WO 86 04801 A (SEALE ET AL.) 28 August 1986 (1986-08-28) * page 12, line 5 - page 15, line 4 * * page 22, line 7 - page 24, line 19 * * page 28, line 14 - page 29, line 12 * * page 48, line 23 - page 49, line 12 * * figures 1,2 *	1,5-9, 15-19, 22,26,27	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	2 August 1999	Chen, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)